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CONTENTS

Integration in Exploration — *Cecil H. Green* — 365

The Discovery History of the University Oil Field, East Baton Rouge Parish, Louisiana — *Gordon Atwater* — 371

Geophysical Exploration by Telluric Currents, with Special Reference to a Survey of the Haynesville Salt Dome, Wood County, Texas — *Eric Boissonnas and Eugene G. Leonardon* — 387

Low-Speed Layer in Water-Covered Areas — *Frank Press and Maurice Ewing* — 404

Explosives Accidents on Geophysical Crews — *P. M. Hanahen* — 421

Analysis of Total Magnetic-Intensity Anomalies Produced by Point and Line Sources — *Roland G. Henderson and Isidore Zietz* — 428

The Determination of an Infinite Inclined Dike from the Results of Gravity and Magnetic Surveys — *Laszlo Egyed* — 437

Is It an Anomaly? — *R. Maurice Tripp* — 443

Ocean Bottom Sampler for Ships Under Way — *J. L. Worzel* — 452

Discussions and Communications — 457

Patents — 460

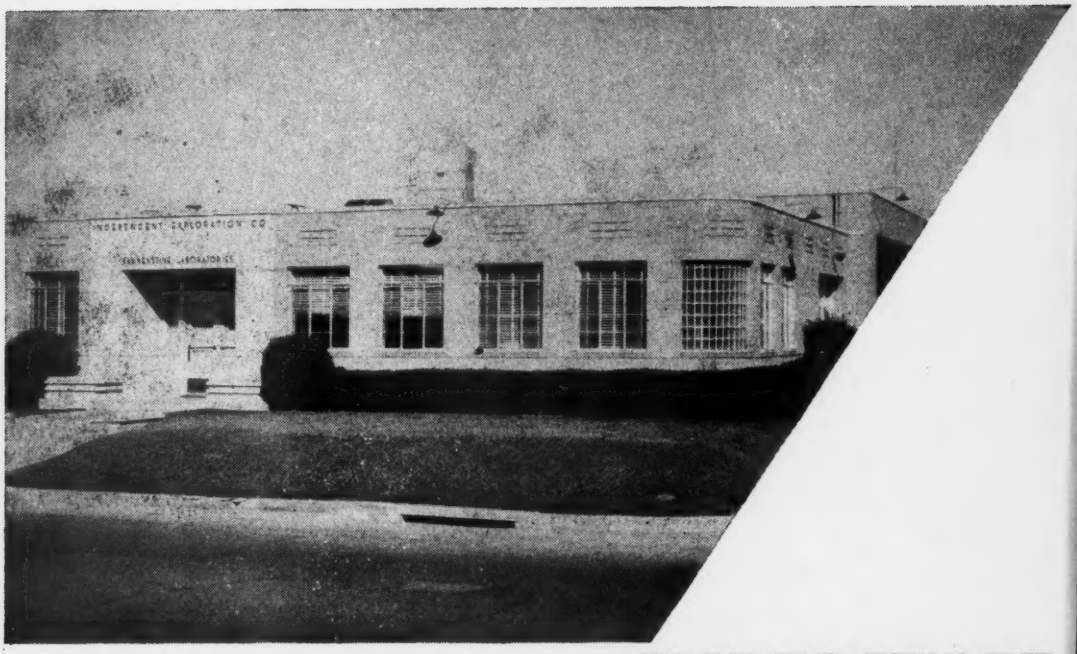
Reviews — 480

Publications Received — 486

Contributors — 487

The Society Round Table

- Officers for the Year Ending March, 1949 — 492
- Papers Presented at the Eighteenth Annual Meeting — 493
- Minutes of the Annual Business Meeting — 507
- Annual Award for Best Paper — 520
- Papers Presented at Meetings of the Local Sections — 521
- Announcements — 521
- Personal Items — 526
- Membership Applications Approved for Publication — 528



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VOLUME XIII JULY, 1948 NUMBER 3

GEOPHYSICS

A Journal of General and Applied Geophysics

INTEGRATION IN EXPLORATION*

CECIL H. GREEN†

It is a particular privilege to address not only geologists, paleontologists, and geophysicists of the petroleum industry, but also a group of specialists in mining exploration. To you who are mining geophysicists, I hope that I am correct in assuming that the philosophy of my discussion does have a considerable bearing also upon the search for new ore deposits, even though colored by constant reference to petroleum.

No doubt, exploration has attained a new high level of importance in the mining field, as it has for petroleum, where the current rate of domestic oil production has reached an all-time maximum—even exceeding widely the greatest rate established during World War II.

The ratio of annual production vs. proved reserves is an important indicator of condition. In the domestic oil industry we have been able to do no better than to maintain a near-constant value for this index over the 11-year period from 1937 through 1947, even though the total expenditure for exploration—leases, geological and geophysical work plus wildcat drilling—has increased more than four times during the same period.[1]

Looking to the future, it is at least conjectural whether or not we shall be able to maintain the same ratio of annual production vs. proved oil reserves for a similar new period by the sole process of increasing 1937 expenditures another four times. Actually, such an accomplishment is probably dependent upon the strategy of following several other avenues, as well as this one of increased effort; for example,

a. To discover an extensive new province, such as the continental shelf, which we are now entering,

* Presidential Address presented at the Annual Meeting of the Society of Exploration Geophysicists, Denver, Colorado, on Tuesday, April 27, 1948.

† Geophysical Service Inc., Dallas, Texas.

[1] H. J. Struth, "1947 Oil Discoveries Largest Since 1937." *The Petroleum Engineer, 19* (January, 1948) 51–58.

b. To effect distinct improvements in the performance of present geophysical apparatus,

c. To improve the integration of existing exploration methods.

You will note that I have not included the possible invention of an entirely new exploration method—the explanation being that in studying the magnetic, gravitational, electrical, chemical, radioactive, and acoustical properties, we are apparently utilizing already practically every physical property of the earth.

Therefore, in the absence of immediate prospects at least, for a panacea, it appears more necessary than ever to direct our thinking towards sharpening present exploration tools and to better coordination of their use. In other words, the effectiveness of future exploration programs would seem to depend more than ever upon how well we can combine good instruments and capable people.

Of these two elements, capable people is the more important, as indicated by the diversity of talents required in the following exploration pattern.

First, if our field efforts in a particular region are to count for much, we must have direction. This means that logical inspiration must first be provided by a digest of geological background information in combination with all available and pertinent geophysical data. It follows that the accuracy, and hence the value of such preliminary information, is completely dependent upon the caliber and practical experience of the men performing this coordination work. Certainly, they must be more than pure geologists or geophysicists, but should be a combination of both. Because of the time factor requisite to obtaining experience, these dual attributes are not apt to be found in either equal or high degree among men of junior rank.

The field geophysicist may point to the list of oil and gas fields for which he can claim credit. His pride is justified for a job well done, perchance in spite of such factors as remoteness of location, adverse climate, difficult terrain conditions, and to which is usually added, poor quality of data, or complicated interpretations or both. However, credit for the fact that his efforts terminated in positive, rather than negative results, must often be shared with geological-geophysical coordinators, whose planning and authority originated the projects. By way of example, the geophysicist finds it difficult to satisfy an oil company that is undertaking geophysical work for the first time. All of us have probably heard the discouraged words of the non-technical wildcatter who, on the basis that an exploration method must be either fully reliable or completely unreliable, decided to abandon completely a particular geophysical method, which after a trial or two had failed to produce an unequivocal result.

It can truly be stated, that the easily found structures or anomalies have been discovered already in most domestic oil provinces, so any extensive oil finding campaign must include marginal areas in point of workability. Therefore, to obtain the highest degree of positive results in the future, the geophysicist will be more than ever dependent upon a management, which in being well informed on the attributes as well as the limitations of the various exploration methods, can supply skilled guidance, supported with patience and fortitude.

The actual conduct of the field program is no less important than its planning. Here also, mental caliber, experience and coordination of talents are of paramount importance. Key personnel are required for three functions; these are: management of the party, interpretation of geophysical data, and geologic orientation. In seismograph operations, which often attain elaborate (and expensive) proportions, separate men may be required to fill adequately these three roles. In fact, there are often field circumstances where less than three men would be expensive in terms of results. The feature of geologic orientation is particularly important; for instance, in being fully apprised at the outset regarding the geologic premise for entering the particular area, the instrumentation and computing techniques can be adjusted to best cope with the anticipated problems at least as they are initially conceived. In serving as a liaison between the party chief (or seismologist) and the management-exploration staff, the geologic observer can contribute information which may indicate the proper solutions for unexpected difficulties such as peculiar weathering situations, lack of sensitivity, unusual reflection or refraction events, etc. There is also the economic point, that the field program can be changed immediately as results begin to modify, or even disprove the initial hypothesis.

It is likely that petroleum will continue to be found indefinitely by reworking old areas in greater detail, or with instrumentation especially adapted to each particular problem. It is also natural to assume that major undiscovered pools lie concealed in regions which so far have yielded an unusable variety of geophysical data. The Delaware Basin of West Texas, the Michigan Basin, and the Tejon Ranch Area of California are prime examples for the seismograph at least. Undoubtedly, the geophysicist will find himself ever confronted with a frontier dividing workable from non-workable areas. Though he can point with justifiable pride to the distance this frontier has been pushed back to date, nevertheless, the task grows increasingly difficult. So a third unit in the exploration organization is assuming increasing importance; I refer to a liaison research and engineering department between the field and the geophysical laboratory.

Two examples from the reflection seismograph illustrate the function of this liaison department and its range of interest. First, basic field research could involve studies of sonic wave propagation with a view to accomplishing a reduction in the ratio of disturbance to reflection energy, or for improving the ability to resolve more closely spaced reflections, etc.; second, engineering effort would continue to focus upon improving electrical characteristics of the recording system in terms of sensitivity, frequency discrimination, volume-control action, etc. Then there are the practical physical aspects of reduced weight of instruments, as opposed to greater ruggedness, plus increased ability to withstand extremes of temperature and humidity.

A final and equally important link in the exploration organization is the review section, wherein all forms of exploration data are consolidated. This entails the amalgamation of information from a wide variety of sources; this could include geologic interpretations from outcrops, core drilling, electrical, radioactivity

and density logs from deep wells, geochemical evidence, all combined with various geophysical reports. Here again, the personal factor is important, since the effectiveness of such review and coordinating effort is dependent upon qualities of wide experience, imagination, and skill. The review section chief, located in either the district or headquarters office, should have a direct connection to exploration management, so as to have a voice in shaping the course of further exploration, or development, as the case may be. Because of this relationship, he should appreciate the importance of making a forceful presentation of data, with proper accent given to the salient features of an anomalous situation by the skillful coloring of maps having a common scale.

It follows that review work must be considered for each area as often as a new control is added. Here is an excellent opportunity for the man with a curious and imaginative turn of mind to recast a previously indeterminate piece of geophysical evidence in the light of some new supplementary data! Certainly the resulting hypothesis could create the best lead for a fresh geophysical investigation. Without such a review section, one might say that a few oil fields are "lost" in the files.

The importance of skill, experience, and coordination of men within the exploration industry has been stressed, but there is another personnel aspect that should be considered—that is to say, the future effectiveness of the exploration industry, say ten years hence, is dependent upon the caliber and training of university graduates who are now entering the profession. In looking back ten years or more, we recall that geophysical work possessed the lure and romance of a new profession, plus a compensation differential high enough above the average industrial level to overcome any hesitation. But today, exploration geophysics does not possess these two inducements. So, we are doing an average job of competing for desirable new personnel. I have heard the question asked, "Why should a man elect to move around in a situation of difficult housing, when he can obtain easily a position in one place in many other lines of engineering endeavor, and for about the same gross income?" Fortunately, there seems to be a growing realization that incompetence in geophysical interpretations is costly at any price, while in contrast, an alert, resourceful and experienced geophysicist can be cheap at almost any price. Three recommendations are offered:

1. Publicize exploration on an industry-wide basis, so that undergraduates will have the earliest opportunity to elect geology and especially geophysics for a career.
2. Offer advice to interested universities on suitable curricula, which should stress a broad science training. Major studies should include mathematics, physics, geology, etc., with minors in chemistry, English, languages, etc. Laboratory work should be restricted to demonstrations of fundamental principles pertaining to the various geophysical methods.
3. Give the same assurance of future prospects to the young man, whether he starts out as a geophysicist or a geologist.

Recognition of the importance of the preceding aspects of integration to effective exploration is reflected in the activities of the Society of Exploration Geophysicists.

First, I would mention the compilation of a new Cumulative Index of our journal GEOPHYSICS. This presents a complete list of technical articles by authors, also by subject classification, through 1947. Patents pertaining to geophysics are listed in a new section by inventors' names, also by subject, through 1946.

Second, a campaign to accumulate over fifty geophysical case history papers, covering a wide range of producing fields, has been successfully completed. This collection will appear next fall in Volume I of a proposed Geophysical Case-History Series.

Third, I would make special mention of the organization to date of six local sections—first in Tulsa, then in Dallas, Houston, Shreveport, Fort Worth, and in the Los Angeles-Bakersfield Area. As intimated previously, there is a need to develop men who are competent in both geology and geophysics. Geophysicists have benefited greatly from local section meetings and distinguished lecture tours of the AAPG. If as a consequence, the average geophysicist knows more about geology than the average geologist about geophysics, then here is our opportunity to offer recompense. The SEG local sections are created at a time when exploration geophysics seems to be fast losing the aspect of secretiveness. The pooling of common knowledge and experience is started already. For instance, our Los Angeles-Bakersfield section has held two symposiums to date; the first on "Multiple Reflections," and the second on "Correlation of Reflections." The Dallas section plans to present a symposium on an important topic of equal common interest at a regional meeting next fall. To stimulate interest and to further understanding of the common ground between geology and geophysics, the suggestion has been made that joint field trips should be organized and conducted by experienced geologists and geophysicists, with emphasis placed on structure and lithology, rather than upon the details of stratigraphy and nomenclature. Certainly by such collective efforts the art should progress much faster than by separated endeavors.

The interest of the Society towards inducing and preparing engineering and other undergraduates for exploration geophysics is centered in two standing committees: one for "Student Membership," and the other for "Geophysical Education." This interest has been reciprocated fully, since we can now count over seventy student members. We can also point with pride to two newly formed student chapters—one at the University of Tulsa, with the other here at the Colorado School of Mines.

No one can deny that the exchange of ideas on instrument design, which has been carried out over the years between geophysical research men, has been of great benefit to the exploration industry. However, there is also the aspect that novel suggestions, leading to advancements of more radical character, might be derived from sources anywhere in the broad field of electronics. With this thought

in mind, the SEG, in conjunction with the American Institute of Electrical Engineers and the Institute of Radio Engineers, is forming a liaison committee to survey the applications of electronics to exploration geophysics.

I wish to again refer to the mining specialists as I conclude this portrayal of the necessity for sharpening existing tools and coordinating the use of every kind of ability and method. It is my understanding that new discoveries are needed as badly in the mining as in the petroleum industry. On the premise that geophysical efforts must be increased in the mining industry, the Society of Exploration Geophysicists is happy to arrange at this convention a special symposium for producing an exchange of ideas between the two industries.

It is evident that exploration efforts should be united upon a single wide base instead of continuing to follow separated channels of mining and petroleum. Therefore, it is the hope of the Society that this first joint meeting with the mining specialists, which is held appropriately in Denver, will initiate a permanent working relationship for the benefit of all exploration.

THE DISCOVERY HISTORY OF THE UNIVERSITY OIL FIELD, EAST BATON ROUGE PARISH, LOUISIANA*

GORDON ATWATER†

ABSTRACT

The localized occurrence of salt water in shallow wells on and near the Louisiana State University campus, in addition to shells collected during the drilling of these wells, attracted the attention of geologists to this area prior to 1926. A torsion balance survey in 1931 was followed by a dry hole drilled in 1933 southeast of the present field. Three separate reflection seismograph surveys during the period of 1934 to 1937, on each one of which a well was drilled without establishing production, were made on the University structure prior to discovery in 1938. The location based on the first reflection seismograph survey should have resulted in the discovery of both the shallow and deep production, and the discovery location was finally made because of the oil and gas shows encountered in this abandoned test. After discovery, an additional reflection survey was made to detail the structure as an aid in development.

The University Oil Field, East Baton Rouge Parish, Louisiana, is located on the east bank of the Mississippi River immediately south of the town of Baton Rouge, and includes within its productive limits a part of the campus of Louisiana State University. The field lies in the Mississippi River alluvial valley and on the adjacent dissected upland. Its location in relation to other producing areas in Southeastern Louisiana is shown in Figure 1.

The field, discovered early in 1938 by William Helis and Louisiana Crusader Oil Company, has produced some 21,500,000 barrels of oil to April 1, 1947. Early production was obtained from shallow Miocene sands ranging in depth from approximately 4,000 feet to 7,100 feet, with the main producing horizon and discovery sand of the field occurring at approximately 6,500 feet. Deeper production from the Marginulina section was discovered late in 1941 in sands from approximately 9,200 feet to 10,000 feet. A total of 139 wells has been drilled in the field to date, of which 109 were completed as oil wells, 11 as gas wells, and 19 as dry holes. During the flush period of shallow production, early in 1940, daily production reached a maximum of 11,000 barrels. The shallow production has been essentially depleted and is now in the late stages of gas-lift operations. At present the daily production averages about 5,500 barrels, of which approximately 3,500 barrels are being produced from 22 deep wells. Shallow production is still obtained from 43 wells.

When Professor Henry V. Howe arrived at Louisiana State University in the summer of 1922 to join the faculty of the Department of Geology, a shallow water well was being drilled to a depth of about 1,100 feet in the southern portion of the campus. Dr. Howe visited the well shortly after it started and obtained a sizeable

* Presented at the Joint Regional Meeting of the Houston Geological Society and the Houston Section of the S.E.G., March 26, 1948. Manuscript received by the Editor June 26, 1947.

† Consulting Geologist, New Orleans, Louisiana.

collection of fresh and brackish water shells. When, a few years later, a well was drilled about four miles southeast of the campus near the residence of one of Dr. Howe's students, he acquired a similar collection of shells at a depth several hundred feet greater than that of the University well. His curiosity now aroused,

FIG. 1. Map of portion of southeastern Louisiana, showing location of University Field.

he gathered all the records of water wells that could be found in the area and from them, particularly from a well at the Cinclair Sugar Refinery across the river, came to the conclusion that the University well was structurally high. This appeared to be confirmed by the occurrence of salt water in wells ranging in depth from 300 to 700 feet in the vicinity of the University campus. Wells drilled in the City of Baton Rouge, and also to the east, west, and south of this area, obtained fresh water from sands encountered at similar depths. Sometime about 1926 Dr. Howe started discussing with his students the possibility of there being an oil field on the edge of the University campus and suggested that if any of them should ever be in a position to check the area with geophysical instruments, that

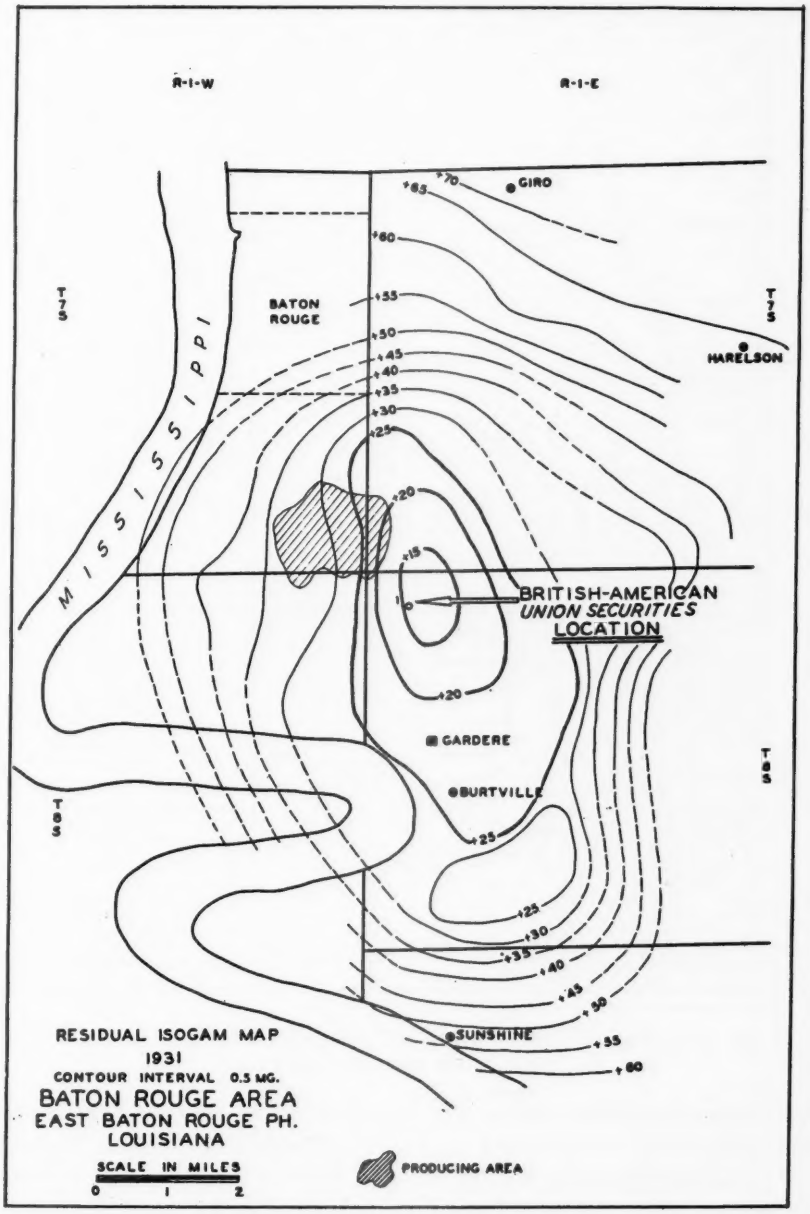

FIG. 2. Residual gravity map, Baton Rouge Area, Louisiana, 1931. Contour interval 0.5 mg.

they do so. Karl E. Young was the first student to be in a position to follow Dr. Howe's advice, and early in 1931 the Torsion Balance Exploration Company was employed by Young and his associates to make a torsion balance survey of the

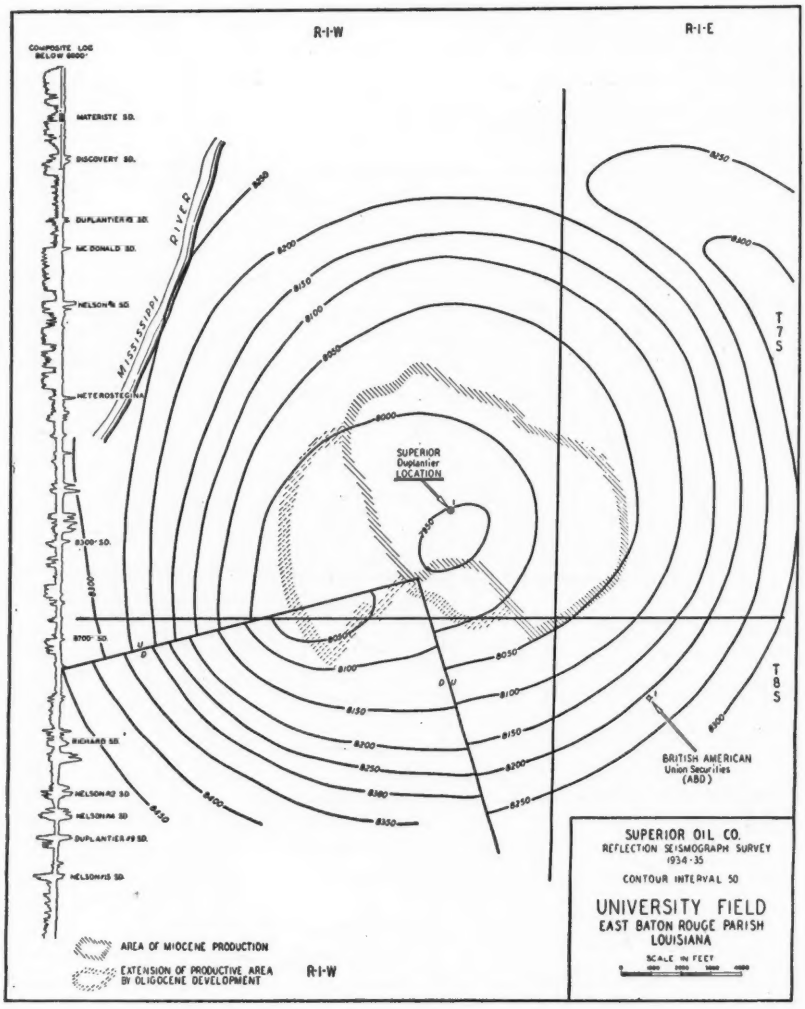

FIG. 3. Reflection seismograph map, Superior Oil Co., 1934–35. Contour interval 50 ft.

area. Figure 2 shows the residual gravity minimum presented in the report prepared by this company following the survey. The area outlined by Isograms 15, 20 and 25 was highly recommended.

In the latter part of 1932, Young and Lowrie prepared a geological and geophysical report on the possibilities of this area, in which they interpreted the structure as a salt dome where salt would be found at a depth of approximately 6,500 feet. A drilling block of 9,960 acres was assembled, and in 1933 was assigned to the British-American Oil Company, who drilled the No. 1 Union Securities at the location shown in Figure 2 to a depth of 6,515 feet and abandoned it as a

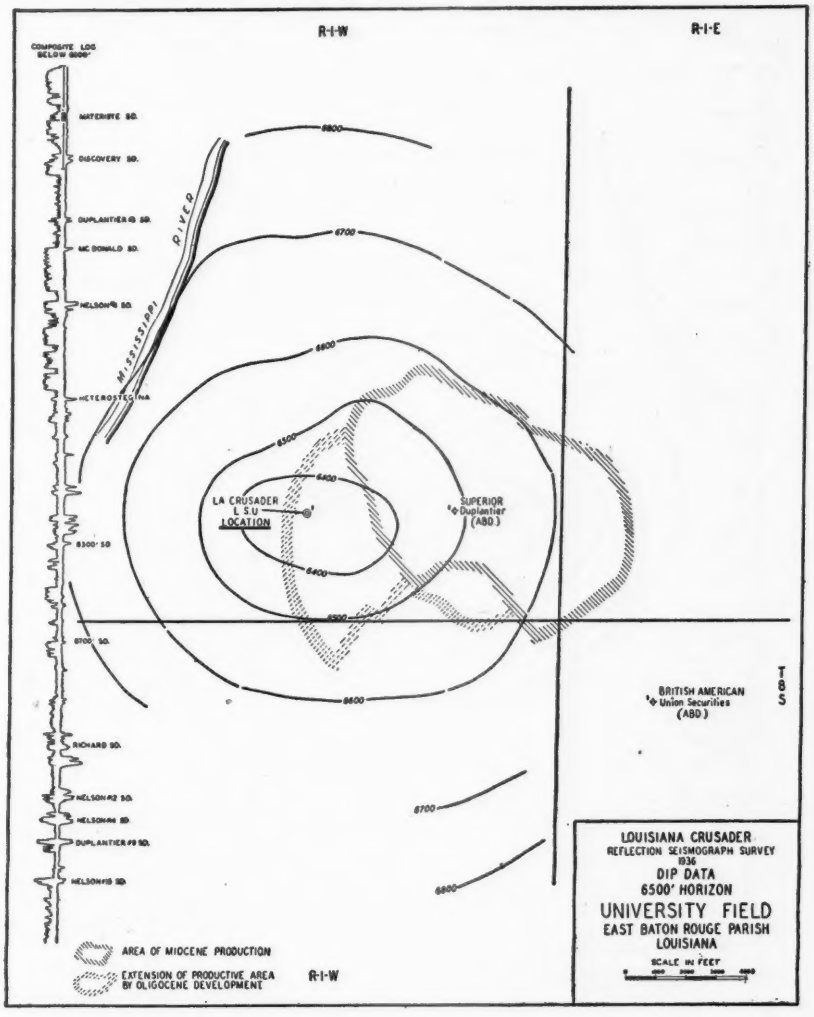

FIG. 4. Reflection seismograph map, Louisiana Crusader Oil Co., 1936, from dip data at 6,500 ft. horizon.

dry hole in December, 1933. This well is located approximately 3,500 feet southeast of the productive area of the field.

Following the drilling of this well, the British-American Oil Company reassigned the block to Young and Lowrie, who then turned it to the Superior Oil Company of California late in 1934. The Superior Oil Company had, previous to this acquisition, done some reflection seismograph work in the area, and after the acquisition further reflection work was undertaken with their own company crew. The results of these two reflection surveys, using both dips and correlations, are shown in Figure 3. Additional acreage was taken to bring the total amount

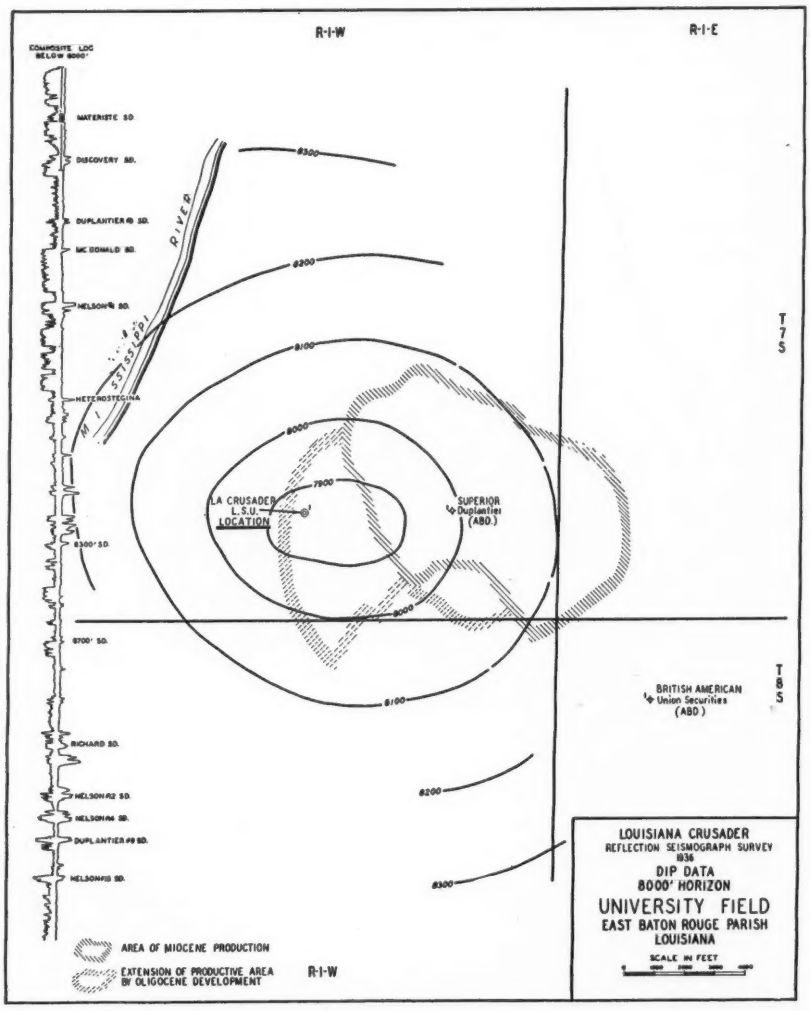

FIG. 5. Reflection seismograph map, Louisiana Crusader Oil Co., 1936, from dip data at 8,000 ft. horizon.

under lease by The Superior Oil Company to around 9,000 acres, which included 2,200 acres of the Louisiana State University lands. The No. 1 Duplantier was drilled at the location shown in Figure 3. Considerable trouble was encountered in drilling this well, and the hole, after being lost as a result of a cavity encountered in the Heterostegina limestone at approximately 7,700 feet, was sidetracked and drilled to a total depth of 10,360 feet, encountering numerous shows of gas and oil. A protection string of casing had been set above the Heterostegina limestone, and when drill pipe was stuck at total depth the pipe was cut and recovered to the base of the protection string. The casing was perforated in what

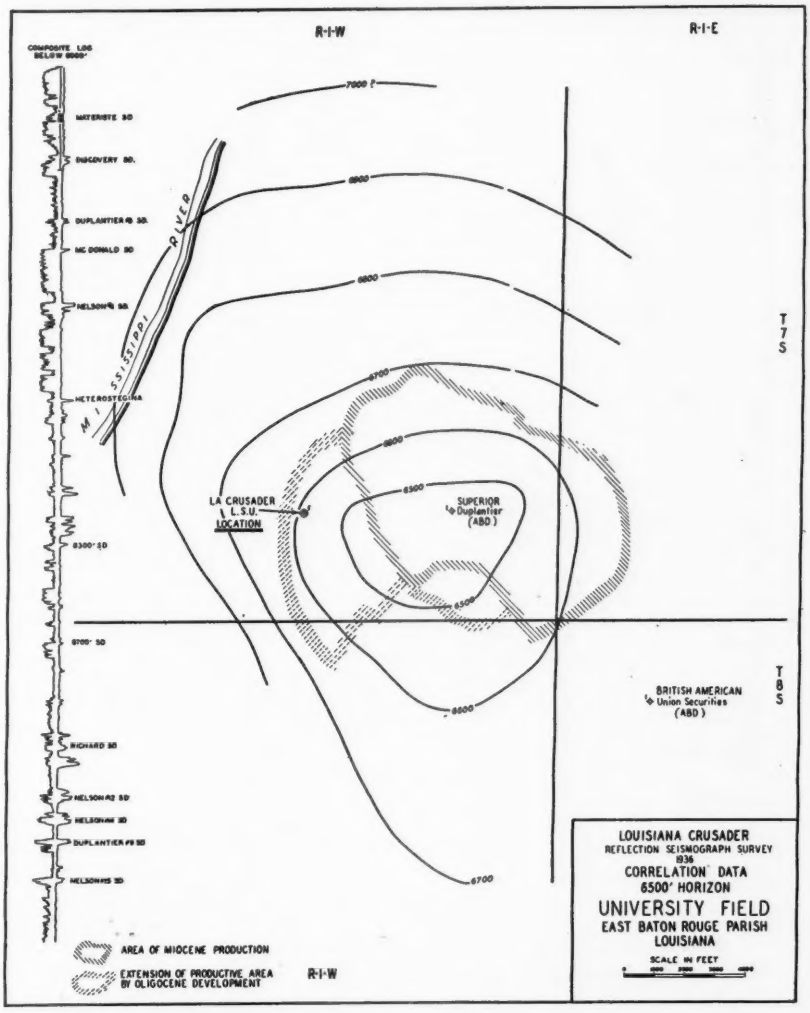

FIG. 6. Reflection seismograph map, Louisiana Crusader Oil Co., 1936, from correlation data at 6,500 ft. horizon.

was later to be the discovery sand for the field and a drill stem test showed good pressure, recovering considerable gas and quantities of 33° gravity oil and salt water. Without additional testing the well was abandoned in the fall of 1935. The Superior Oil Company, while holding a substantial lease position in the block, gave up some of the acreage including the lands of the Louisiana State University.

Louisiana Crusader Oil Company entered the prospect when they employed South Texas Geophysical Corporation in 1936 to make a reflection seismograph survey of the prospect. The work was done in two stages, the first of which con-

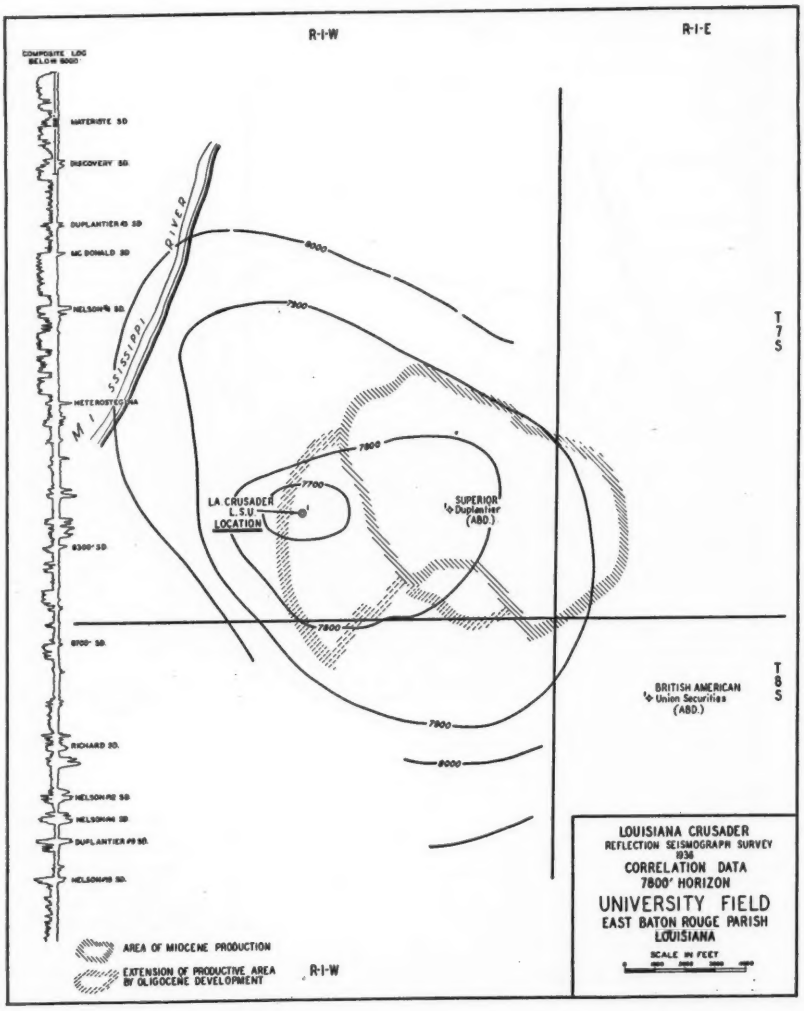

FIG. 7. Reflection seismograph map, Louisiana Crusader Oil Co., 1936, from correlation data at 7,800 ft. horizon. Probably on reflection from Heterostegina limestone.

sisted of one continuous profile north and south across the top of the prospect and an east-west line across the south side of the University property. Because of the favorable results of this preliminary survey, additional work was undertaken, consisting of continuous profiles as well as a number of random shotpoints with straddle spreads to obtain the vector gradient. Some trouble was encountered in obtaining useable records and many points had to be reshot. Figures 4 and 5 present maps on the 6,500 foot and 8,000 foot horizons, based on dip data alone, and Figures 6 and 7 present maps on the 6,500 foot and 7,800 foot horizons based on correlation data. Figure 8 presents a map based on the average of all the dip

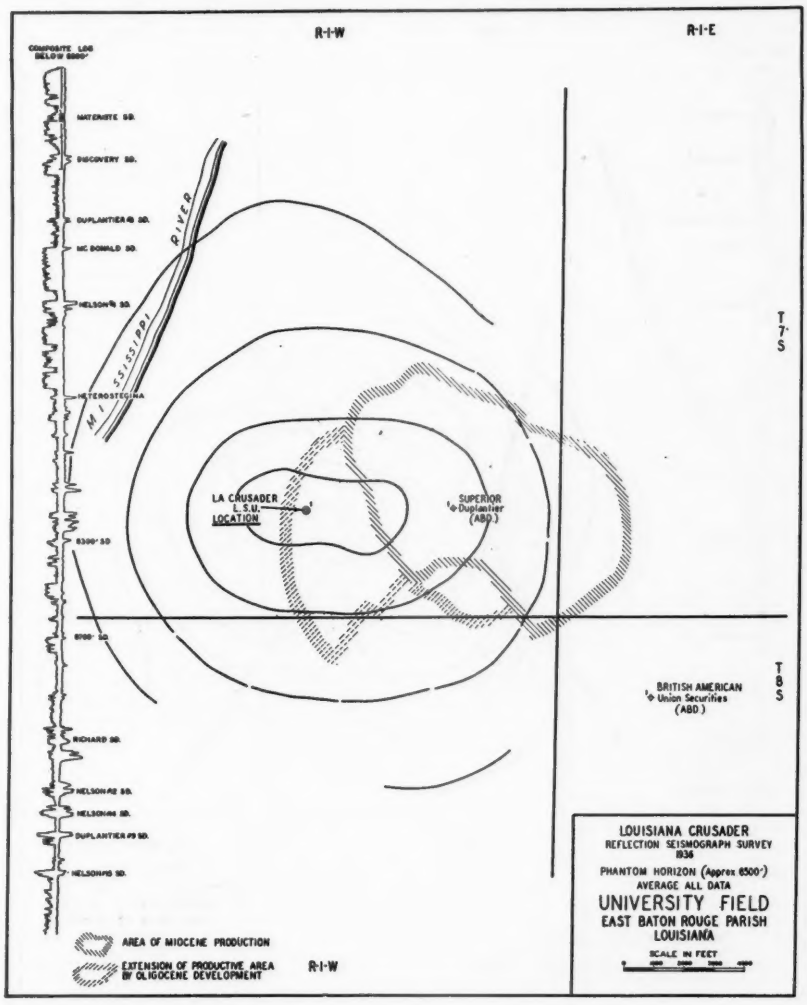

FIG. 8. Reflection seismograph map based on all dip and correlation data of Figs. 4, 5, 6 and 7; phantom horizon at approximately 6,500 ft. (1936).

data and correlation data. This phantom horizon was at approximately 6,500 feet. It was felt that the maps based entirely on correlation data were less reliable than those based on dip data.

It is interesting to note that the picture on the 6,500 foot horizon based on correlation data (Fig. 6) most nearly conforms with the structure of the 6,500 foot horizon (Fig. 9). The western portion of the field, shown on most of the 1936 seismograph maps as being the apex of the structure, actually contains the highest fault block in the field, but this area is structurally high by virtue of a recovery fault, and a picture showing the true dip of the beds would show west

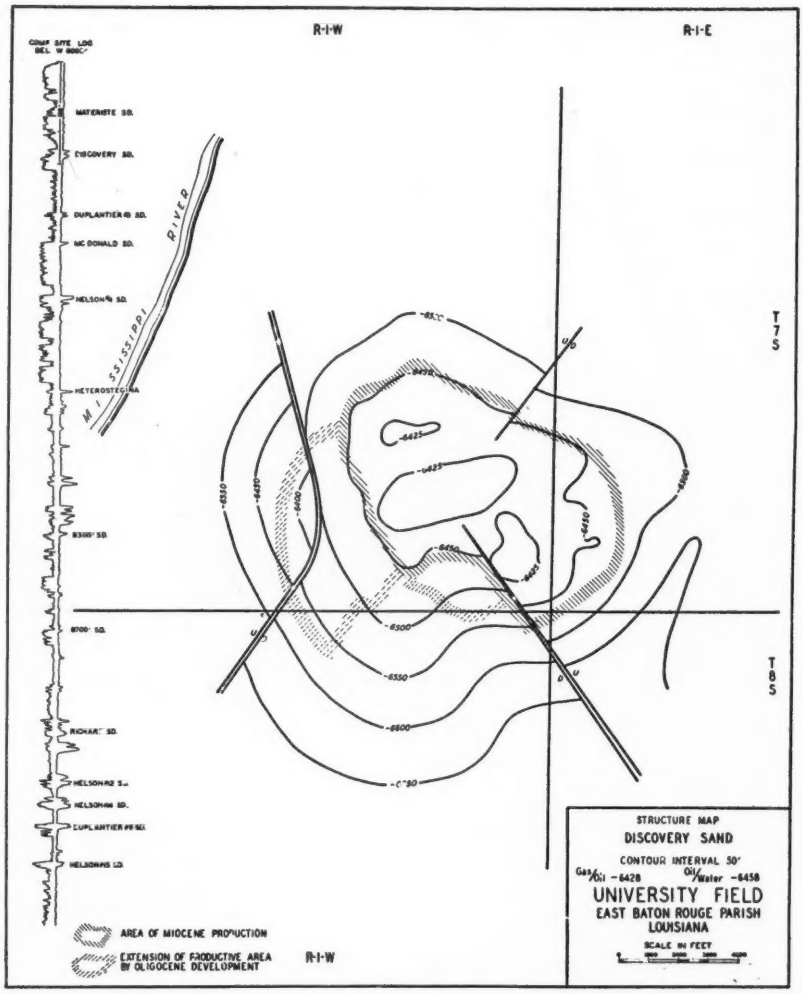

FIG. 9. Subsurface contours on discovery sand.

dip in the western half of the productive area. The correlations on the 7,800 foot horizon (Fig. 7) are almost certainly based on reflections from the Heterostegina limestone, the structure map of which is shown in Figure 10.

As a result of this work, a location for the Louisiana Crusader No. 1 L.S.U. was made approximately 5,000 feet west of the abandoned Duplantier test. This well was drilled to a total depth of 7,260 feet and abandoned in December, 1936.

Early in 1937 Louisiana Crusader did additional reflection seismograph work in the area, employing Hoard Exploration Company. A consistently good reflection at about 1.9 seconds, assumed to be the top of the Heterostegina lime-

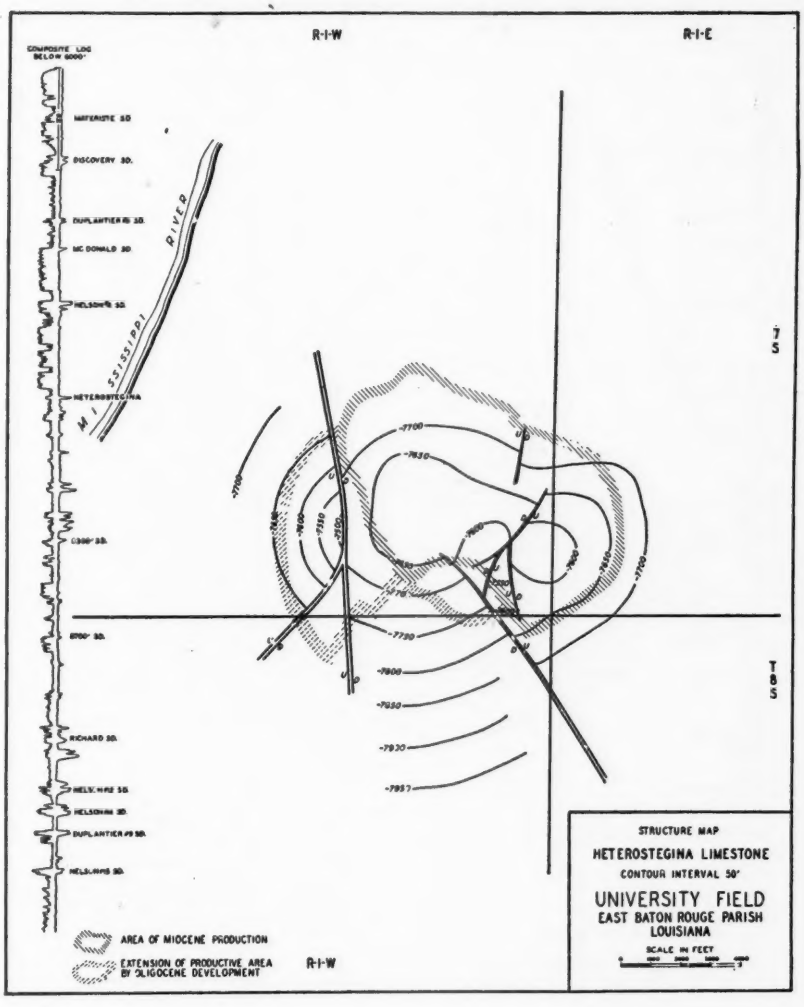

FIG. 10. Subsurface contours on Heterostegina limestone.

stone, was mapped with both slope and correlation shooting, and the resulting picture is shown in Figure 11. The results of this shooting, strikingly similar to those obtained in the earlier work for Louisiana Crusader, led to the location of the Louisiana Crusader No. 2 L.S.U. well, approximately 1,000 feet south of their No. 1 L.S.U. This well was abandoned as dry in July, 1937, at a total depth of 8,531 feet. The 6,500 foot horizon, that had good oil and gas shows in the Duplantier well, was encountered at a higher structural position in the two Louisiana Crusader dry holes. There was, therefore, good reason for believing that the two areas were separated by a recovery fault striking in a north-south direc-

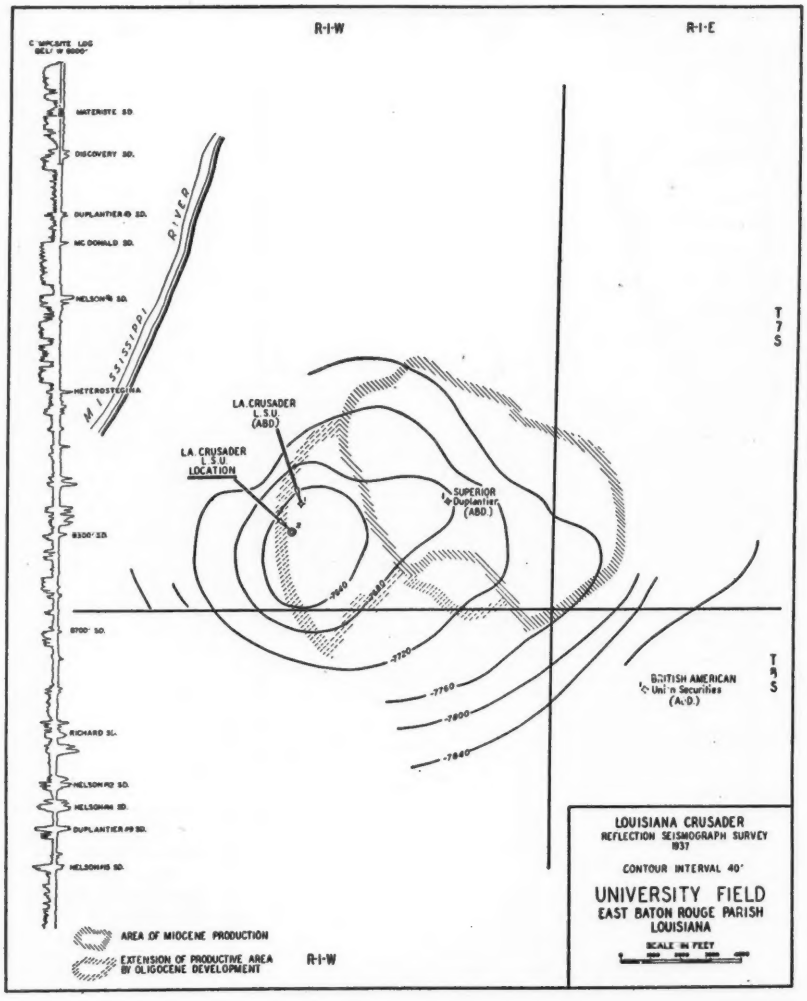

FIG. 11. Reflection seismograph map, Louisiana Crusader Oil Co., 1937, contours probably on reflection from Heterostegina limestone, based on both dips and correlations.

tion and dipping to the east, and evidence of missing section was found in these two wells.

In the latter part of 1937 and the early part of 1938, the Louisiana Crusader added to their block by leasing property dropped by The Superior Oil Company and by farmouts from that company. At this point, geophysics was temporarily forgotten and a location made for the No. A-1 Duplantier well 400 feet southwest of the old No. 1 Duplantier abandoned well (Fig. 12). This well was completed as the discovery oil well March 22, 1938, at a total depth of 6,477 feet in the same oil sand that was tested in the No. 1 Duplantier. The initial daily potential of this

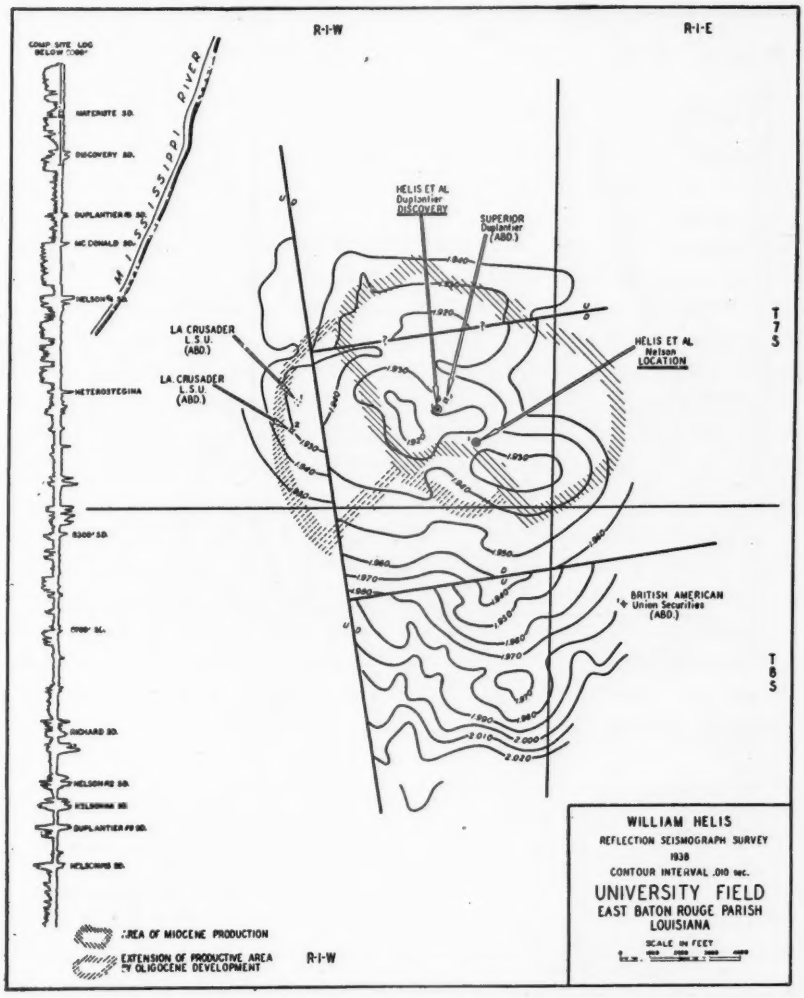

FIG. 12. Reflection seismograph survey, William Helis, 1938.

well on a 3/16 inch choke was 524 barrels of 33.2° gravity oil, with 5 percent BS&W and with tubing pressure of 990 pounds. Before the drilling of this well, William Helis had acquired a half interest in the Louisiana Crusader block, and upon completion of the discovery well, Helis took over the operations of the field.

Simultaneously with the drilling of this well, Hoard Exploration Company was employed to make a detailed geophysical survey of the block. This work was done by continuous profiling, using eight detectors spaced 150 feet apart, with a tie between spreads by means of a common instrument. The subsurface coverage per seismogram was 525 feet and shooting distances varied from 0 to 4,000 feet, with the set-up nearest the shotpoint usually resulting in poor records. Shot-

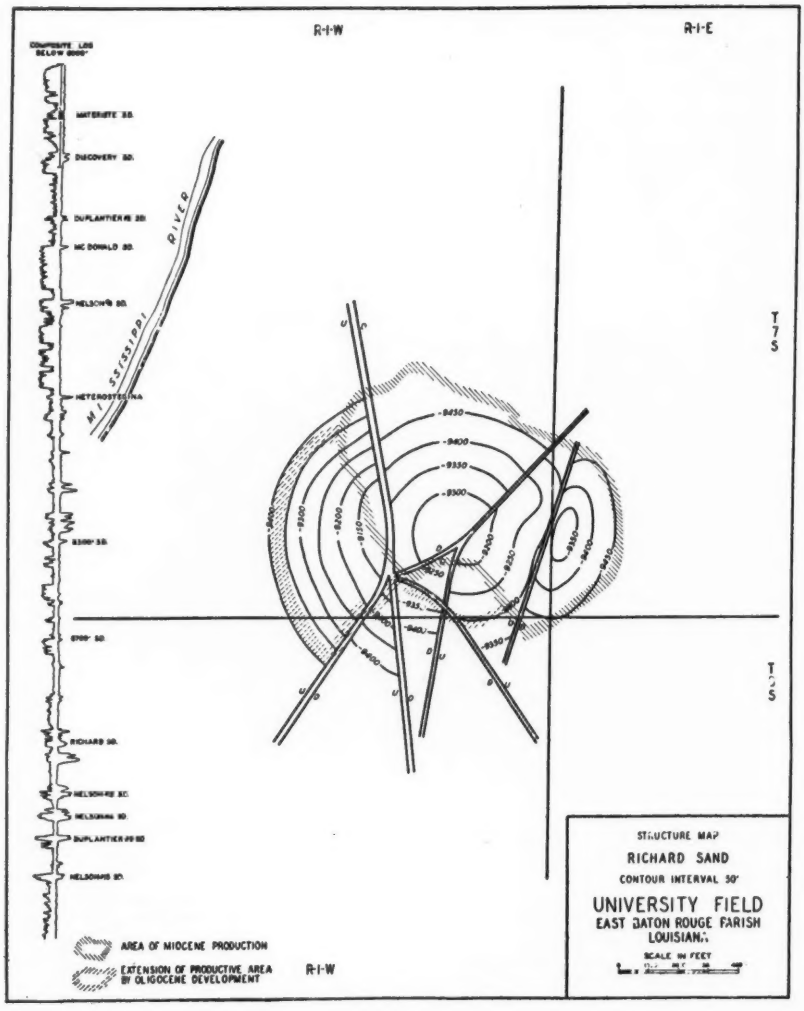

FIG. 13. Subsurface contours on Richard sand.

points were placed in the line of instrument set-up. A fairly continuous reflection at approximately 1.9 seconds represented the Heterostegina limestone, and this horizon was used in mapping. Figure 12 presents the contour map based on this work, and was prepared by a geologist from the profile sheets. Three faults, one of which was considered very questionable from the records, were mapped. This fault and the other east-west striking fault were not proven by later drilling, but the north-south fault on the west side of the field was mapped essentially correctly. The location for the No. 1 Nelson well (Fig. 12) approximately 1,600 feet southeast of the discovery well was made from this work, which was used in the

development drilling of the field. A considerable degree of correspondence between this picture and the subsurface picture as developed by drilling (Figs. 9 and 10) will be noted.

After the development of the field was well underway, the old No. 1 Duplantier abandoned well was re-entered and a successful completion as a pipe-line oil well was made by squeezing and reperforating the same zone that had been tested when the well was drilled.

The deep production below the Heterostegina was opened up in December, 1941, when a well in the eastern part of the field was drilled to a total depth of 10,017 feet and completed in the Nelson No. 12 sand at approximately 9,500 feet. Figure 13 presents the structure contour map made on the Richard sand that occurs at approximately 9,200 feet. The striking feature of the faulting in this field is the increase in complexity of the fault pattern in the Heterostegina and older beds. In most of the deep wells the same difficulty is encountered in penetrating the porous Heterostegina limestone as the Superior found in drilling their test. The presence of porosity in this section cannot be predicted from the present structural position of the well on the Heterostegina zone, and the writer believes that this porosity is the result of localized solution of the limestone by circulating ground waters related to an old erosion surface that probably existed locally in the area shortly after Heterostegina time. The disappearance of many of the faults in the section above the Heterostegina may be taken as support for the belief that one period of the structural growth of the University Dome coincided with the end of Heterostegina deposition, followed by local emergence and ground water movement.

The most recent phase in the discovery history of the University Field occurred late in 1943, when deep production was established west of the major north-south fault in the western portion of the field. As now drilled, it is apparent that there is no accumulation in this western recovery block to correspond with the shallow Miocene production in the central and eastern portions of the field. It would thus appear that the last major structural movement in the University area, during which the major part of the dome was dropped below the level of the western fault block, occurred after the accumulation of the shallow Miocene oil, and that during this period of accumulation the western flank of the field, in so far as the Miocene beds are concerned, was continuous with and structurally lower than the major portion of the dome.

Early in 1946, during the development of the deep production, the stuck drill pipe that had been left in the old No. 1 Duplantier well below the bottom of the 7 inch pipe was recovered from the hole and the well completed in the Nelson No. 12 sand as a pipeline oil well. The first well drilled on the structure following the initial seismograph work was thus definitely proven to be satisfactorily located to discover both the shallow and deep production in the University Field.

In summary, it would appear that the initial reflection seismograph work done by The Superior Oil Company satisfactorily outlined the University Field

structure, and discovery should have been made on this picture. In fact, the ultimate discovery of the University Field was complicated and delayed by later geophysical work and the area was probably over-shot. The first well drilled on the structure should have been the discovery well of both the shallow and the deep production, and it was only when operators returned to the immediate vicinity of the initial location that the area became productive. The last generation of detailed geophysical work done by the major operator in the field aided the development geologist, but no oil was found that would not have been discovered through routine development of the producing area.

ACKNOWLEDGMENTS

The writer wishes to thank the William Helis organization, Progress Petroleum, Inc., and The Superior Oil Company of California for release of information presented in this paper, as well as John C. Myers for making available information and reports from his files.

GEOPHYSICAL EXPLORATION BY TELLURIC CURRENTS, WITH SPECIAL REFERENCE TO A SURVEY OF THE HAYNESVILLE SALT DOME, WOOD COUNTY, TEXAS*

ERIC BOISSONNAS† AND EUGENE G. LEONARDON†

ABSTRACT

The fact that natural currents flow through the ground has been known for quite a long time. Some of these currents are local in character; some involve the whole of the earth's surface. These latter currents are called telluric currents. Their behavior and properties are outlined in general, and their usefulness for the practical purpose of geophysical exploration is discussed at length. In conclusion, an example of an actual survey by telluric currents on the Haynesville Salt Dome (Texas) is given, which illustrates the quality of the results which can be obtained in similar cases.

INTRODUCTION

The object of this paper is to discuss the results obtained in a survey of the Haynesville Salt Dome, Texas, by telluric currents. This survey took place in the spring of 1947. Inasmuch as no telluric current work of any substantial extent was known to have been performed as yet in the United States, it was hoped that such a survey would give a good illustration of the results that could be achieved by this type of exploration on problems amenable to it.

The dome has been known to exist for a long time. It measures more than 2 miles in diameter, in an E-W direction, and about $2\frac{3}{4}$ miles in a N-S direction. The salt has been encountered at a depth a little over 1,200 feet on the top. The dome is unproductive and there are very few pipe lines above it or in its neighborhood, a favorable factor with respect to the reliability of the measurements.

The work was carried out by a reduced crew, operating two instruments only, one at the base station and one at the points of observation. The number of stations computed was 72, covering an area of about 30 square miles. With a fully manned crew (2 mobile recorders), the number of measurements would easily have been 175. Mention should also be made that a density of $2\frac{1}{2}$ points per square mile corresponds to detailed work. In the case of general exploration, areas up to 250 square miles per month can be surveyed.

The first measurements made in the United States by telluric currents are, to our knowledge, those of R. S. Dahlberg, Jr., which are reported in the October 1945 issue of GEOPHYSICS.[1] They were few in number and do not constitute an exhaustive trial of the process. Another reference in the English literature to this

* Presented at the meeting of the Houston Section of the S.E.G., March 26, 1948. Manuscript received by the Editor February 14, 1948.

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[1] R. S. Dahlberg, Jr., "An Investigation of Natural Earth Currents," *Geophysics*, X (October, 1945).

phase of electrical prospecting is the paper presented by Marcel Schlumberger at the meeting of the American Geophysical Union at Washington, D. C. in April, 1939.[2] This latter paper is interesting because it discloses examples of field work, in particular the exploration of some 150 square miles of ground in the potash basin of Upper Alsace (France). A salt diapyr (elongated salt intrusion) was outlined over a distance of about 20 miles. It would seem that had World War II not occurred at about this time, this kind of exploration would have readily found fields of application, and would be in a much more advanced stage of development than it is today.

No basic article, as yet, has discussed, in English, the general principles underlying the exploration by telluric currents. We shall, therefore, devote quite a large part of this paper to such generalities, with the hope that they may prove convenient and useful to anyone making regular reference to the American geophysical literature. As the bibliography of this paper will readily indicate, the authors claim little credit for this part of their discussion.

THEORY OF TELLURIC-CURRENT METHOD

A few words about resistivity measurements.—Geophysicists are familiar with the method of exploration by resistivity measurements. An artificial current is

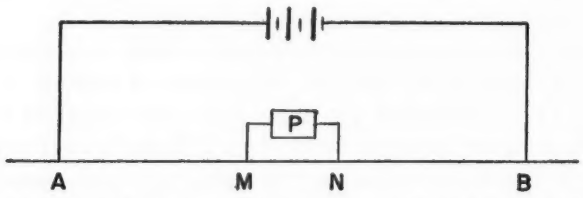


FIG. 1. Surface resistivity measurements using a Schlumberger quadripole.

sent into the ground by means of two electrodes A and B (Fig. 1) which we shall call power electrodes. The flow of this current creates an electrical field which is studied at the surface by means of two measuring electrodes M and N, connected to a potentiometer P. Knowing the respective positions of A, B, M, and N, the intensity of the current flowing into the ground and the difference of potential measured between M and N, it is possible to compute the *apparent resistivity* of the ground in the region MN; in other words, the resistivity of a homogeneous ground which would, under the same experimental conditions, give the same difference of potential between M and N.

Electrodes A, B, M and N are generally on a straight line. It is assumed that, in most cases, the depth of investigation of such electrode configurations is in the order of $\frac{1}{4}$ of the base line AB. Therefore, with sufficiently long lines, one can in-

[2] Marcel Schlumberger, "The Application of Telluric Currents," *American Geophysical Union, Transactions* (1939).

vestigate deep geological features, provided, of course, they are of a sufficient size in terms of the depth and possess the requisite electrical differentiation to make them amenable to electrical prospecting. It is obvious, however, that the laying of several miles of electrical cable on the field for the sake of obtaining a single (or at best a few) measurement is a costly and tedious process. It follows that a great progress in efficiency and cost would be achieved if it were possible to do away with the long line AB, the power electrodes, and the artificial current. It so happens that this feat is possible, due to the existence of telluric currents, which flow through the ground in large sheets at all times.

Various kinds of earth currents.—That currents are flowing through the ground and create differences of potential between two points thereof has been known for a long time. Barlow, in 1847, from his measurements on English telegraph lines, was the first to acquire definite proof that currents flow in the ground.

Some of these currents are man-made, for instance those caused by the operation of street cars, electrified railroads, power lines, mining installations, and the like. Other currents are due to local electrochemical effects. Metallically conductive ore bodies are the seat of permanent electrical activity and behave like huge storage batteries with a negative pole at the apex of the ore body. Other local currents can be ascribed to the atmospheric precipitation or evaporation, the wind, the temperature, and storms, etc.

All of the above phenomena occur in areas of limited extent. In contrast with them are the differences of potentials caused by astronomic phenomena such as the rotation of the earth, the electronic emissions of the sun, etc. These are the result of currents covering exceedingly large areas, in fact the whole globe, and for which reason we shall call *telluric currents*. These currents have been studied for a period of more than 50 years, and the knowledge gained through such studies has been discussed by various scientists. One of the interesting features of these currents is that they circulate in quite vast sheets involving large segments of the earth's surface; they constitute, essentially, four vast current whorls covering the whole globe.

Character of the telluric currents.—The "telluric" component of the differences of potential measured between two points of the ground is roughly proportional (along a given direction) to the distance between these points. This justifies the concept of an average telluric field. Of course, if the points are at too short a distance from each other, the definition of the telluric field tends to become illusory due to other local electrical disturbances whose weight may become abnormally preponderant.

The telluric field, at a given station, varies in intensity and direction. Its daily average is probably equal to zero. Averages over shorter periods, however (an hour or so), show that for the middle latitudes its direction is more or less that of the magnetic meridian. There are two maxima and two minima per day. At lower latitudes, on the other hand, the average vector is almost perpendicular to

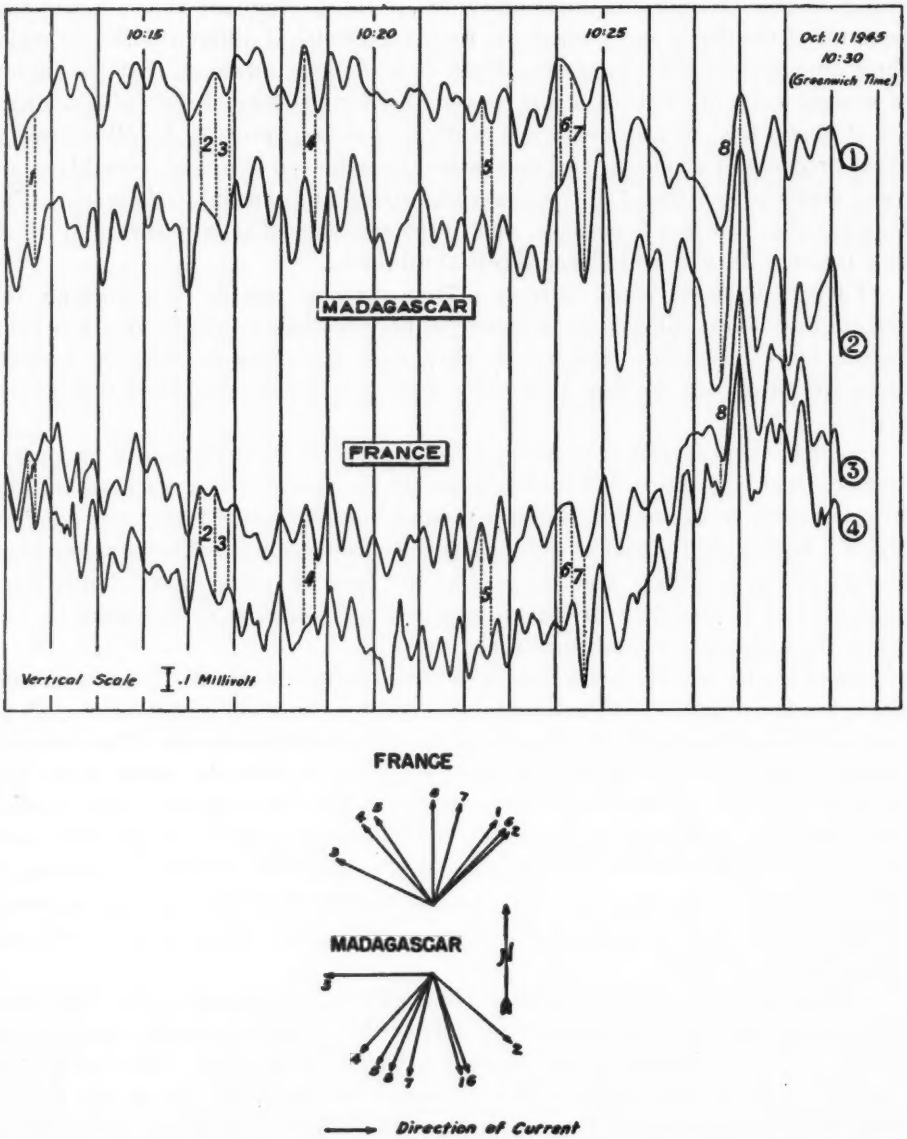


FIG. 2. Simultaneous recording of telluric currents in southern France and Madagascar. Plat below the recorded diagrams indicates corresponding directions of the current at different times.

the magnetic meridian and shows only one maximum and one minimum daily.

More or less intense pulsations are superimposed on the average telluric field. These pulsations are well illustrated on Figure 2, which shows recordings made simultaneously by two crews located respectively in Southern France (Aquitanian

Basin) and in Madagascar.[3] Diagrams 1 and 2 represent the variations of the current in Madagascar along two rectangular E-W and N-S directions. Diagrams 3 and 4 give the corresponding data along a SE-NW and SW-SE direction, in France. The synchronism is obvious and illustrates the interdependence of these vast electrical phenomena. It must be pointed out, however, that the similarity of such simultaneous diagrams at great distances is not always so striking. There are even cases when precise correlations are impossible. Incidentally, it may be observed that when the variation is oriented towards the north in France, it is oriented towards the S-SW in Madagascar. When the variation vector rotates clockwise in France, it turns counter-clockwise in Madagascar, and vice versa. A

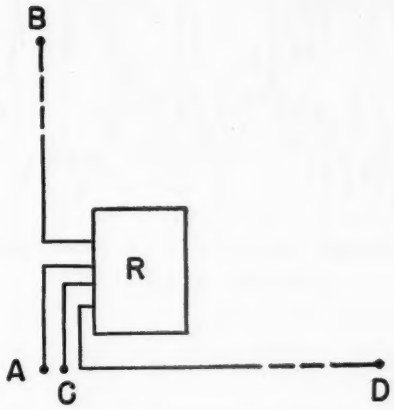


FIG. 3. Electrode set-up for recording of telluric currents.

similar conclusion was obtained by analyzing diagrams taken simultaneously in France and Gabon (Central Africa, south of the Equator), the vectors rotating in opposite directions. On the other hand, between France and Morocco or Tunisia, which are all in the northern hemisphere, the rotation was in the same direction.

A few additional examples of telluric-current diagrams.—Variations of telluric potentials are easily put in evidence by the use of non-polarizable electrodes (Fig. 3). The length of line *AB* is generally 1,500 feet or less. Measurements are made along two rectangular bases *AB* and *CD* (with *A* and *C* practically coincident).* They are recorded on the same photographic film by means of a recorder *R*. They have the appearance shown on Figure 4. In order to readily distinguish one rectangular component from the other, one of the diagrams is registered in the form

[3] Marcel Schlumberger and Geza Kunetz, "Variations rapides et simultanées du champ tellurique en France et à Madagascar," *Extraits des Comptes-Rendus à l'Academie des Sciences, 223* (October 7, 1946), 551–53.

* The bases need not necessarily be rectangular. Should they not be at right angles, the term components, which is used throughout this paper, should be replaced by projection.

of a double line.* The distance between two vertical lines represents a time interval of 30 seconds. It will be seen that in the example given, the telluric potentials undergo pulsations of a period of about 8 seconds. Experience has shown that

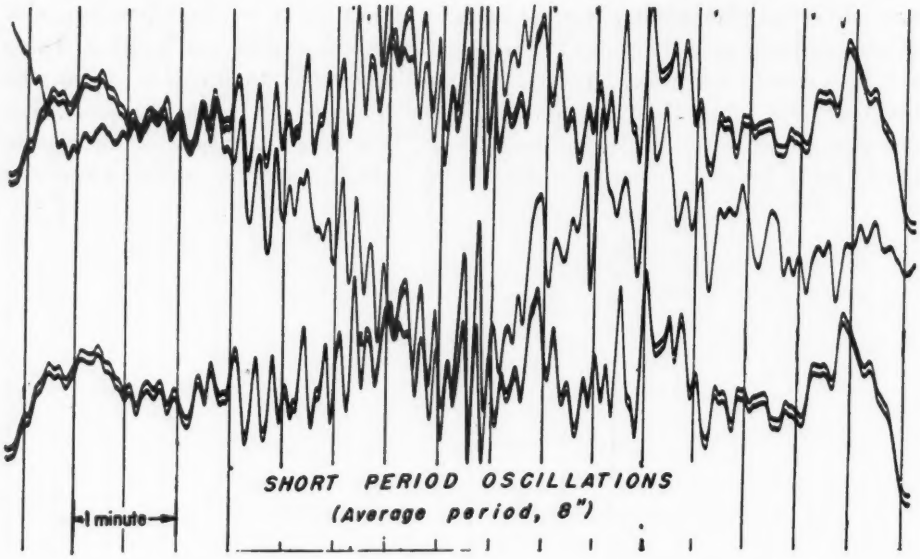


FIG. 4. Example of telluric-current recording (short oscillations).

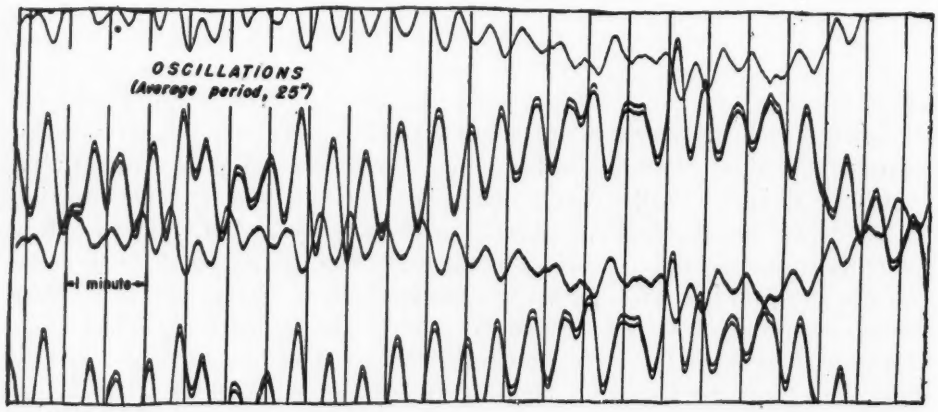


FIG. 5. Example of telluric-current recording (oscillations of about 25 seconds duration).

* Actually, Figures 4 to 7 show duplications of the two diagrams recording the variations of the components. This is achieved by means of an appropriate optical device. Thus, when a graph comes near the edge of the film, its duplication appears on the center of it, a very practical and useful feature.

the period of such pulsations will vary widely from a few seconds to a few minutes (Figs. 5 to 7).

Tranquil and long pulsations seem particularly prevalent at night. Changes

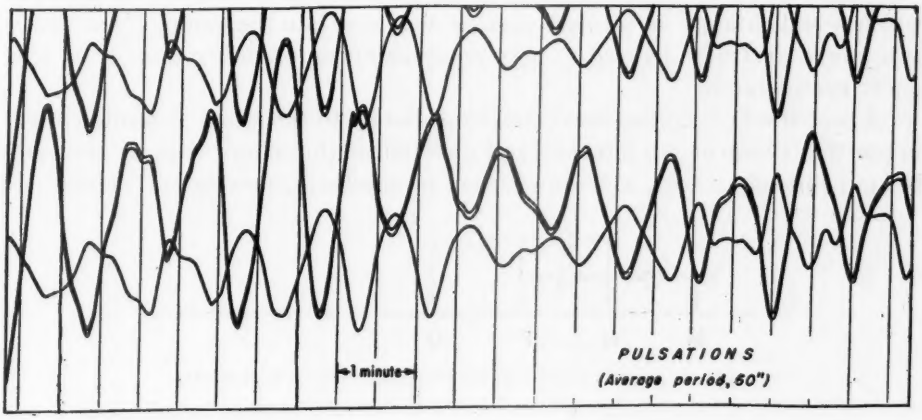


FIG. 6. Example of telluric-current recording (period of oscillation of about 1 minute).

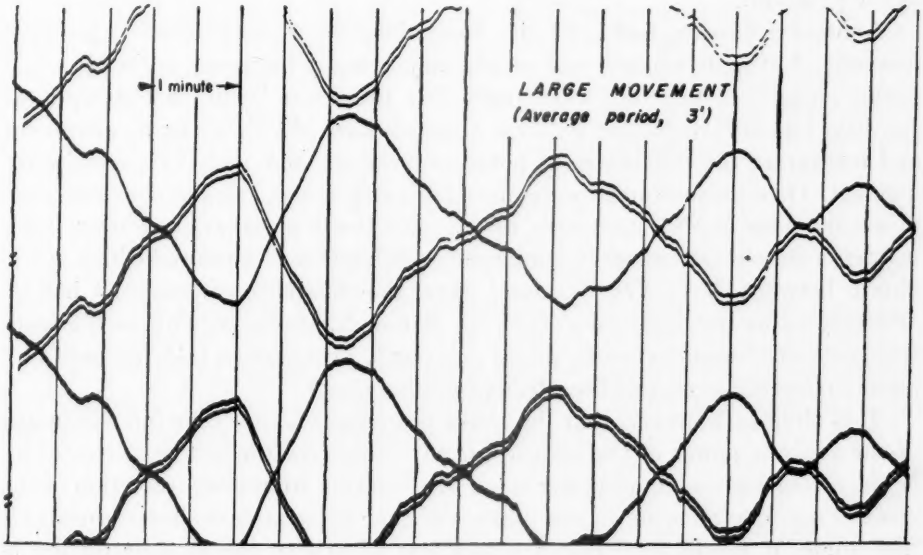


FIG. 7. Example of telluric-current recording (slow oscillations: about 3 minutes).

are more rapid during the day, as a rule, and particularly so during spells of solar activity.

Principles underlying telluric exploration.—Whatever be the cause of the telluric currents, they possess, as already said, the very characteristic peculiarity

of flowing in very large sheets. While their direction and intensity vary constantly as a function of the time, these currents have substantially the same direction *at a given time*, over areas of several thousand square miles. In other words, at a given time, the electrical conditions within a determined area are those which would obtain if an artificial current were sent into the ground by means of two power electrodes located at very great distances, on either side of the area under consideration.

A procedure of exploration comes immediately to the mind. It would consist in plotting a map of the intensity and direction of the telluric field at any number of points of an area, when the current in question is flowing in a determined

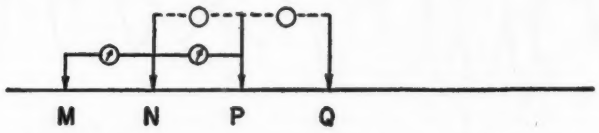


FIG. 8. Telluric measurements on predetermined alignments.

direction and a given strength at a base station. We shall not go into the detail of the procedure, which constitutes the original approach of Marcel Schlumberger to the problem.

Another approach, less attractive from the point of view of strict physical reasoning, but quite efficient and satisfactory in many instances, is the electrical profile along predetermined alignments. The procedure is simple and rapid. It consists (Fig. 8) in displacing by steps a double base $MNNP$ along an alignment and measuring the differences of potential between MN and NP at the same moment. Then the instruments are moved one step ahead, and the same measurements are made in NPQ. Of course, once a full series of observations is over, it is a matter of simple arithmetic to compute the differences of potential which would obtain between MN, NP, PQ, etc., when the difference of potential has an arbitrary value (for instance 1) between M and N. However, with such a leapfrog method of measurements, errors necessarily accumulate, and the need of a base of reference to control the whole profile is evident.

It is obvious, however, that the above procedures do not take full advantage of the analytic power of the telluric current. This versatile source of electricity is like a rotating system of power electrodes working from every direction of the clock. From one moment to the other, the current attacks the formations at a new angle. It would seem that the apparent resistivity can be investigated in every possible direction. We shall now see that this is a purpose that can be achieved.

Mathematical expression of the relationship betweeen the telluric field at two different points.—When the direction and magnitude of the telluric field are known at a given point B, they are also determined at any other point S in the area considered. Electrical equations being linear, the relationship between the telluric

fields at B and S is linear. If x and y (Fig. 9) are the components of the field at B on two axes that we will assume rectangular, and if X and Y are the similar components at S, between the four quantities x, y, X and Y, we have two relations of the type:

$$X = ax + by, \tag{1}$$

$$Y = cx + dy, \tag{2}$$

a, b, c and d being four coefficients that, for a given direction of the axes, are constant for the pair of points B and S. The group of these four coefficients is characteristic of the action of the subsoil on the telluric currents at the point considered.*

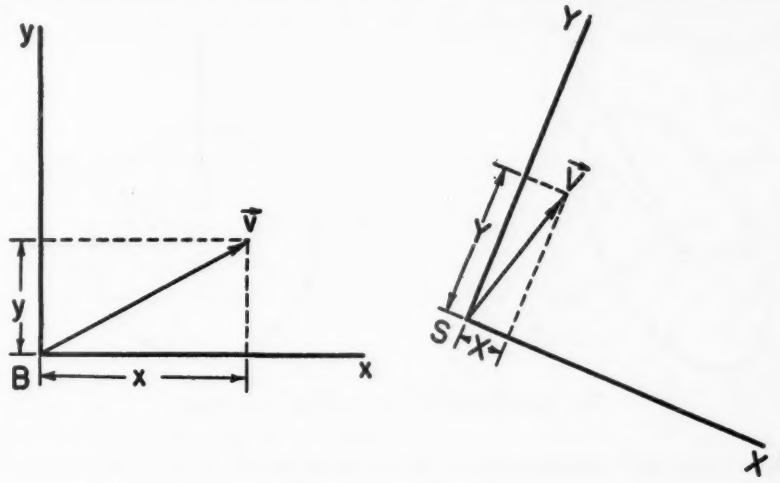


FIG. 9. Relationship between the telluric field at the base and the station.

It is interesting to indicate a concrete representation of the correspondence thus established. Let us suppose that the telluric field at B is equal to 1 and rotates in every direction. Its extremity describes a circle:

$$x^2 + y^2 = 1. \tag{3}$$

With $x = \cos \alpha$, $y = \sin \alpha$, α being the angle of the field vector with the x-axis at B, we obtain in (1) and (2) the following values for X and Y:

$$X = a \cos \alpha + b \sin \alpha; \tag{4}$$

$$Y = c \cos \alpha + d \sin \alpha. \tag{5}$$

* We shall not delve here into mathematical developments concerning the properties of the group (matrix) of the four coefficients $\|ab/cd\|$. However, we shall see below that the expression $ad - bc$ is an invariant of particular significance.

Equations (4) and (5) show that the extremity of the telluric vector at S, corresponding to vectors of magnitude 1 at B, describes an ellipse. In other words, this ellipse gives a complete picture of the direction and intensity of the telluric field at S, when a telluric field of constant magnitude but of varying direction is assumed at B. Should the ground be homogeneous at B, then the vectors of the ellipse would actually represent the relative apparent resistivity of the ground at S in any given direction.

Let us now come back to equations (1) and (2). It has been said that the coefficients a, b, c, and d are characteristic of the action of the subsoil at M on the

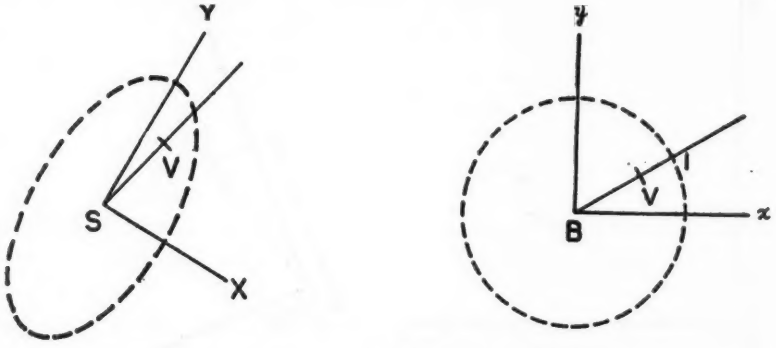


FIG. 10. Construction of the ellipse at a station.

telluric current. As a matter of fact, the expression $ad-bc$ is a very important invariant representing the ratio of the area of the ellipse at S to the area of the circle of radius 1 at B.

The use of this invariant constitutes a very efficient approach to the systematic study of territories explored by telluric currents.

Details of procedure.—There is a first difficulty to overcome in the measurement of the telluric field. It is due to the potentials developed at the contact of the electrodes with the ground. It is a simple matter to build electrodes which possess a relatively constant contact potential. It is, however, another matter to measure this potential. As a result, a more or less constant quantity (constant but unknown) will be superimposed on the value of the telluric field proper.

Fortunately, the telluric potentials vary greatly with the time. If we consider x, y, X, and Y as functions of the time t, equations (1) and (2) become identities. The expressions obtained by derivation of these expressions are still identities. Therefore, the relationship between variations of the components of the telluric field are the same as between the components themselves. Thus, it will not be necessary to operate with the absolute values of the telluric field but with its variations between two determined moments.

For the purpose with which we are concerned, it will be sufficient to record simultaneously the variation of the components of the telluric fields at B and S

(Fig. 10) along two rectangular directions, that is the variations of the differences of potentials along SX, SY, Bx, By, between the same two intervals of time. This series of measurements correspond to a relationship of the type of equations (1) (2). The check on this is easy. It will suffice to consider at B, on the various vectors (such as Bv) the components of which are

$$x_1 - x_0,$$

$$y_1 - y_0,$$

the point at which these vectors intersect the circle of radius 1, and to plot at S, along the direction SV determined by the components:

$$X_1 - X_0,$$

$$Y_1 - Y_0,$$

the corresponding vectors. The extremities of these vectors will be located on an ellipse.

Recordings of telluric currents have been shown on Figures 4 to 7. With a set of two such photographic records obtained at the base and at a mobile station, one will carefully measure a number of variations of potential differences taking

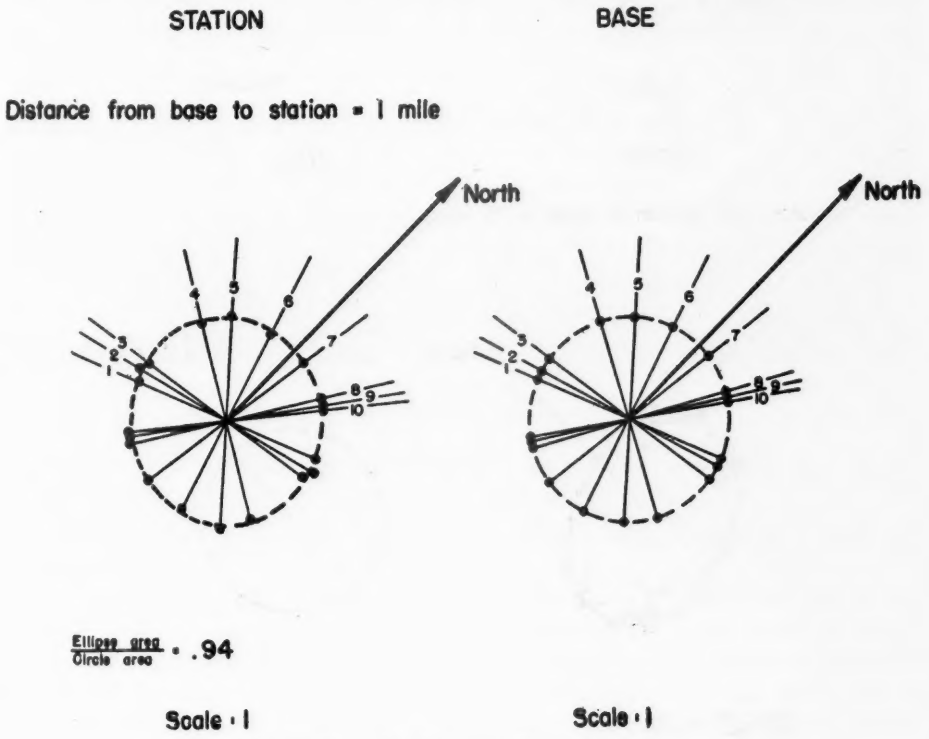


FIG. 11. Example of computation of an ellipse.

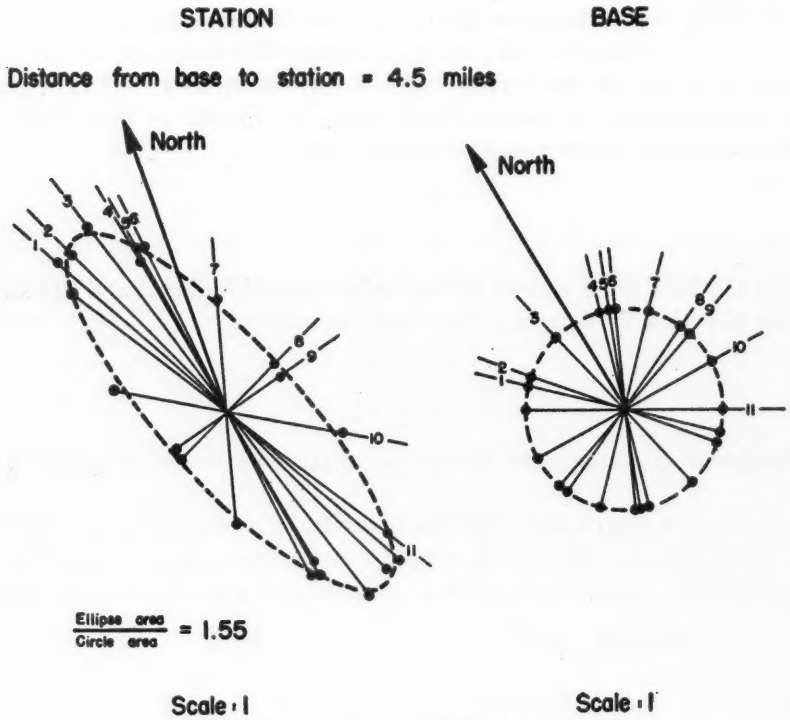


FIG. 12. Example of computation of an ellipse.

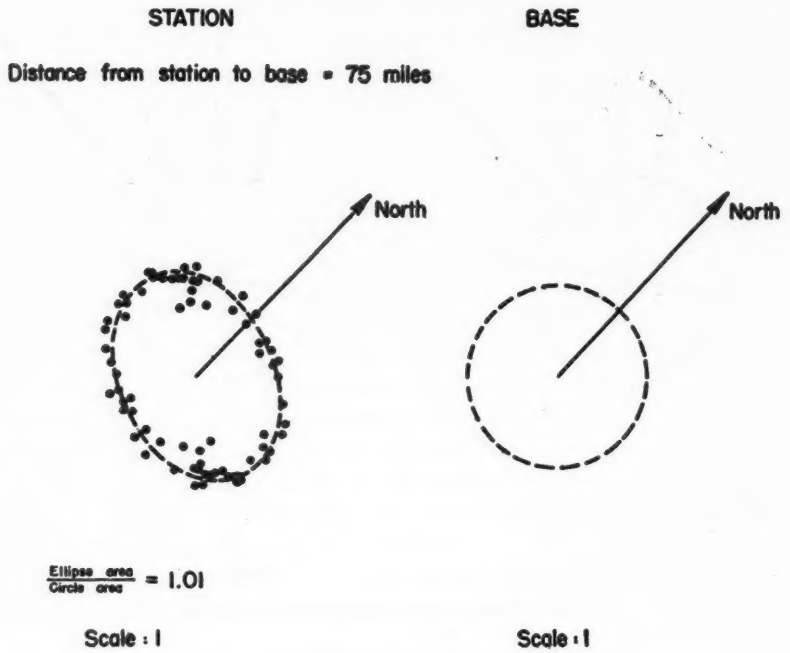


FIG. 13. Example of computation of an ellipse.

place on the two rectangular directions between two given instants. Then with those two sets of vectors one will endeavor to plot numerous points of the ellipse which characterizes the mobile station. Of course, this ellipse will have to be determined with a satisfactory accuracy by a proper number of points. Figures 11, 12, and 13 show examples of ellipses obtained in field work. One will note the distance of the stations, which varies from 1 to 75 miles, as well as the variation of the eccentricity of the ellipses.

FIG. 14. Recorder for telluric-current measurements.

When such a map of ellipses has been completed for a given area, a ready answer can be given to the following problems:

Plot in magnitude and direction the telluric field which corresponds at every station to a given field at the base.

Trace, for the whole area, the lines of flow of current and equipotential curves corresponding to a telluric sheet of a given direction at a certain point.

In practice, it has been found expedient and practical to compute the ellipse areas in terms of the area of the circle of radius at the base station. This comparative value is noted at each station. It furnishes a good all-around yardstick related to the apparent resistivity at the point and constitutes the basis of the interpretation.

Equipment.—The equipment is simple. It is made up of nonpolarizable electrodes, a photographic recorder (Fig. 14), and some insulated cable. It is mounted on a light automotive vehicle (jeep, for instance, Figure 15). A regular

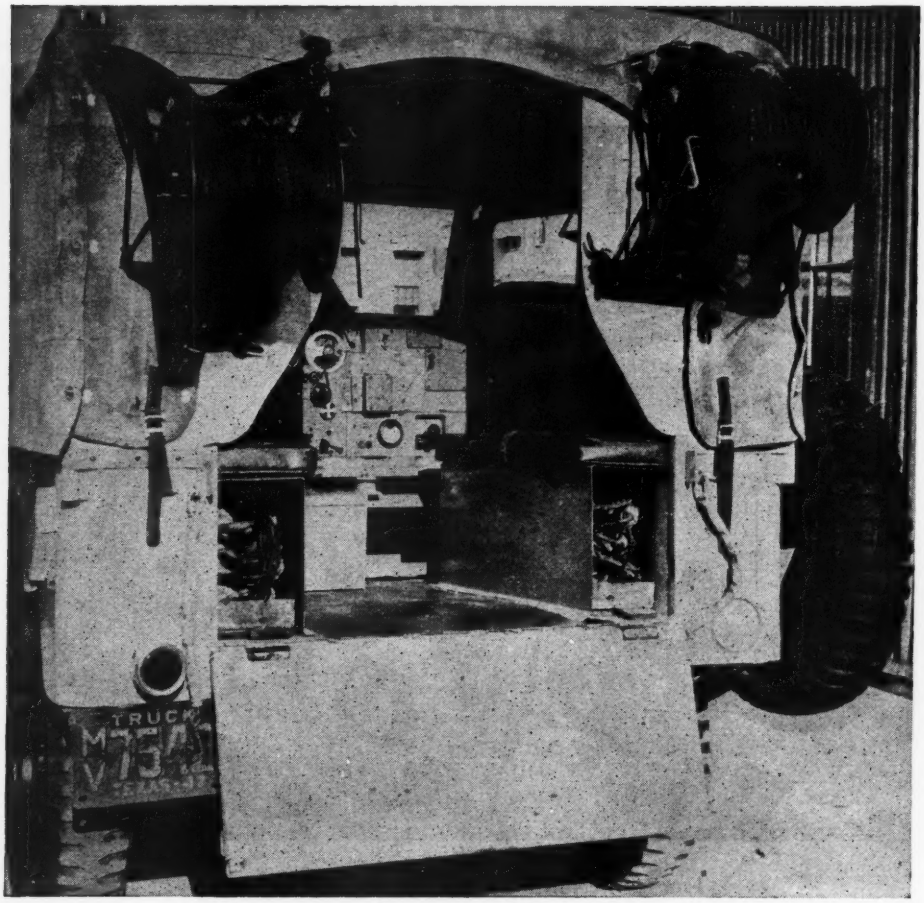


FIG. 15. Vehicle equipped for telluric exploration.

party has 3 such recorders: one stays at the base, and the two others operate at the mobile stations.

When the country is not very accessible (lack of roads, vegetation, etc.), the equipment can be carried on pack animals or even by hand. There is no piece of it that weighs more than 110 lbs. This is quite an advantage in primitive territory.

Problems amenable to telluric exploration.—In principle, all those geological anomalies that will cause a current flowing horizontally and parallel-fashion to be disturbed are amenable to telluric exploration. For instance, a salt dome, as the

example of the Haynesville dome shows, deflects the current because the salt plug is nonconductive.

Folded formations are generally anisotropic. The current progresses more easily along the bedding than perpendicularly thereto, with the result that the telluric vector will show an increase at the apex of an anticlinal or domic structure (Fig. 16).

Faults may be detected if the succession of beds in both compartments of the fault is of such electrical characteristics as to cause a concentration of current along the fault. This will depend on the resistivity of the various beds, their size

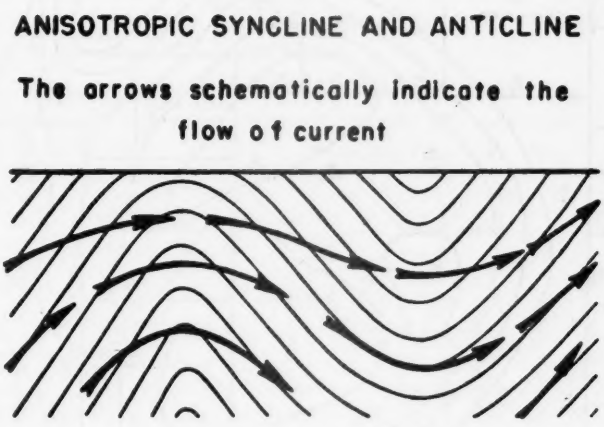


FIG. 16. Flow of the telluric current in an anisotropic folded ground.

and positions. Buried ridges, variations of altitudes in the basement rocks are also favorable problems.

Naturally, whatever be the distortion produced in the current field at the seat of the geological-geophysical anomaly, it must come to the surface with sufficient strength to be detectable. Hence, the deeper the structure, the greater the size of the anomaly must be. The layman (and the geophysicist too, for that matter) will find it quite helpful to visualize the problem at hand in terms of a body of water flowing parallel and quietly as is the case of a river. Changes in the speed of flow, surges, and whirls occur when the depth to the bottom, or the width of the river vary, or when obstacles and ledges are put across the path of the peaceful flow of the water. The disturbing factors, however, must be of sufficient moment to manifest themselves at the surface, which is the place where they can be observed.

RESULTS ON THE HAYNESVILLE DOME

Because the salt is nonconductive of electricity, the current will be deflected by the salt plug. In particular, there will be a concentration of current above the

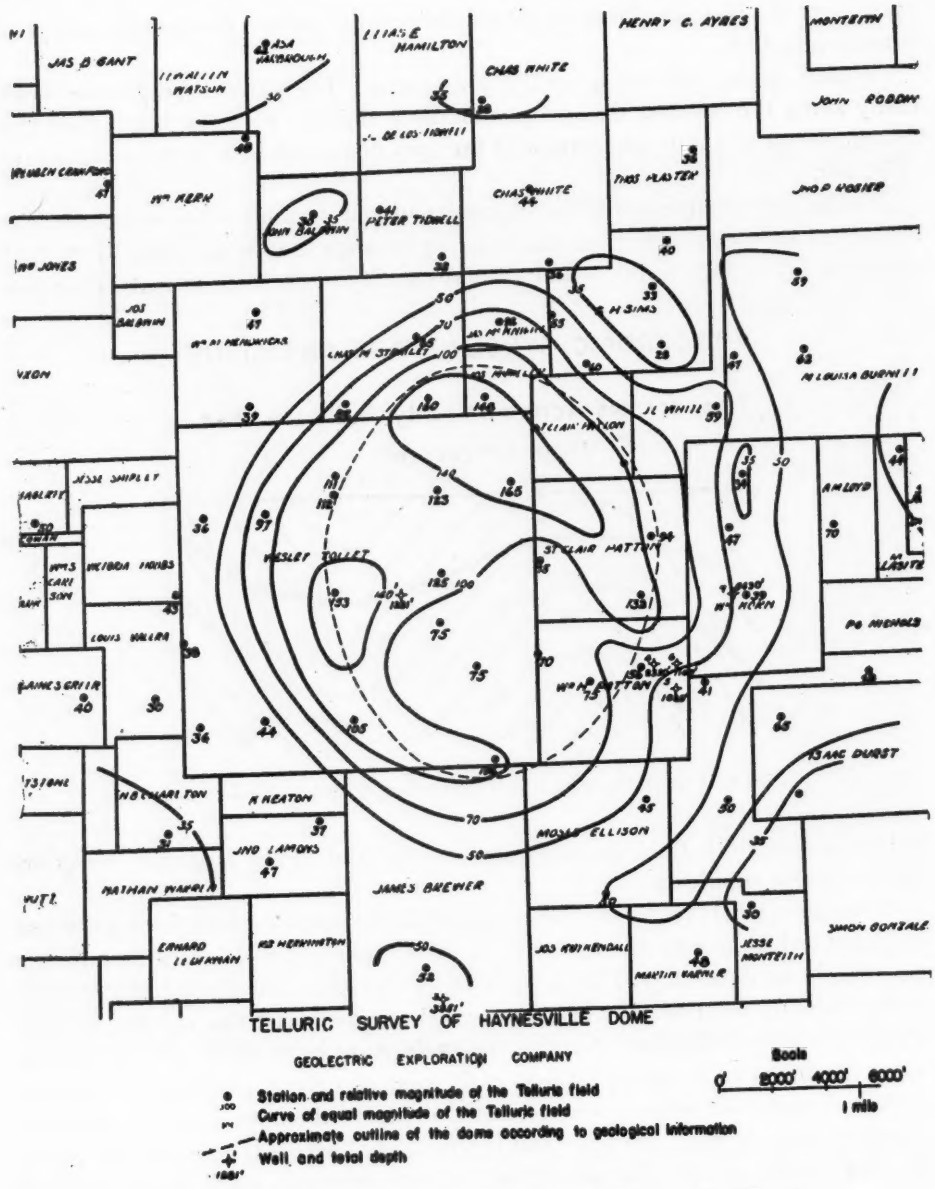

TELLURIC SURVEY OF HAYNESVILLE DOME
GEOLECTRIC EXPLORATION COMPANY
Scale
0' 2000' 4000' 6000'
1 mile
Station and relative magnitude of the Telluric field
Curve of equal magnitude of the Telluric field
Approximate outline of the dome according to geological information
Well and total depth

FIG. 17. Result of a telluric-current exploration at Haynesville (Texas).

salt dome. This is what was observed at Haynesville. Figure 17 shows the results obtained. The small black circles represent the different stations of measurement. Near each of them is a number. This number indicates the value of the ellipse area with respect to that of the circle at the base station, which has been arbi-

trarily numbered 100. This base station is in the southeast corner of the St. Clair Patton Survey. Contour curves of equal ellipse areas have been traced.

The outline of the dome as known from geological information has been marked, as well as the different wells drilled in the area (six in number within the limits of the map).

The differentiation between the measurements on the dome and away from it is considerable. On the dome we have ellipse areas of 150 to 165, while the surrounding territory shows measurements of 30 to 60, or thereabouts. The ratio is in the order of one to three, and even to five. The contrast is decidedly striking. There is no doubt that the structure could have been more deeply buried and still show very well.

ACKNOWLEDGMENTS

The authors and the company with which they are associated wish to express their appreciation to the Gulf Oil Corporation and the Magnolia Petroleum Company for authorizing them to carry out the measurements on their territory under lease, and extending their assistance in any way that might help in the carrying out of the survey.

BIBLIOGRAPHY

1. *Physics of the Earth*, Vol. 8: *Terrestrial Magnetism and Electricity*, 1939, Chap. 6; Earth Currents," by W. T. Rooney.
2. Paul Rougerie, "Contribution à l' étude des courants telluriques," *Annales de l'Institut de Physique du Globe de Paris*, Vol. 20 (1942).
3. Leon Migaux, "Une methode nouvelle de géophysique appliquée: la prospection par courants telluriques," *Annales de Geophysique*, Vol. 2 (June, 1946).

LOW-SPEED LAYER IN WATER-COVERED AREAS*

FRANK PRESS† AND MAURICE EWING†

ABSTRACT

In many water-covered areas it has been reported that the speed of sound in the topmost layers of the bottom is less than that in water. Several methods of investigating such layers are discussed. The normal-mode theory offers the best method of detecting and investigating a low-speed layer covered by water.

INTRODUCTION

The surface layer on land, sometimes called the "weathered layer," always has a low sound velocity. Its depth is usually determined on land by a short refraction profile or by vertical shooting in a drill hole. Does this low velocity layer continue out to sea? If so, the short refraction profile is inadequate to determine it completely because of the higher sound velocity in water. The availability of boreholes for weathering determinations is likely to be much less than on land. The normal-mode theory of sound propagation, which was first introduced into the literature of seismology in a form appropriate for use in practical problems by Pekeris, probably offers the best method for detection and investigation of a low-velocity bottom. The studies of Ide, in which a constant-frequency sound source was used, have shown the sharp contrast between sound propagation over low-speed and over high-speed bottoms. Some evidence is given that soundings obtained from a conventional fathometer may often be a valuable adjunct.

OCCURRENCE OF LOW-SPEED BOTTOM

Osterhoudt's paper[1] brought to the attention of the authors the importance of the question of whether the "weathered" layer extends out under the ocean, a question which was probably clearly in the minds of people in seismic work who were approcahing the beach from the landward side. He reported depths up to 1,000 feet with velocity 3,800 ft/sec in South Timbalier Bay and adjacent waters of the Gulf of Mexico.

Ewing and Worzel[2] found that the dispersion in the water wave at two stations just off the delta of the Orinoco River was radically different from that found off the east coast of the United States and off several Caribbean islands. It will be shown later that this can be explained by the presence of low-velocity bottom.

* This work represents results of research carried out for the Bureau of Ships of the Navy Department under contract with Columbia University. Manuscript received by the Editor March 15, 1948.

† Department of Geology, Columbia University, New York.

[1] Walter J. Osterhoudt, "The Seismograph Discovery of an Ancient Mississippi River Channel," *Geophysics*, XI (1946), 417.

[2] Maurice Ewing and J. L. Worzel, *Memoir 27, Geological Society of America* (in press).

The refraction travel-time curves in this offshore work seldom have observations at less than about one-half mile, but even these curves showed the probability of low-velocity bottom at the Orinoco Stations.

Ide, Post and Fry[3] working in the mouth of the Potomac River, have found abundant evidence that the sound velocity in the bottom is lower than that in water in the summer time.

Several investigators,[4,5,6] making fathometer surveys, have found a reflecting surface beneath the bottom giving an echo so strong, relative to the echo from the bottom, that it is almost certain that the intervening layer has low sound velocity.

These occurrences support the plausible hypothesis that the low-velocity bottom is most likely to be found in areas of rapid deposition.

METHODS OF INVESTIGATION

Shooting in bore holes.—Any of the conventional methods of "weathering" determination based on bore holes would probably work as well at sea as on land, but one reason for preparing the present paper is that there probably will never be many bore holes available at sea.

Refraction time-distance curve.—Typical records from short refraction shots at sea in a region of high-velocity bottom are shown in Figure 1*A* and *B*. The time-distance curve derived from these and related records is shown in Figure 2. The seismograms show the first arrivals to be low-frequency waves which have come through the ground. They are followed by an abrupt arrival of high-frequency sound, which marks the beginning of the water wave. At practically every station investigated, the high-frequency sound in the water wave arrives superposed on ground waves, and because of dispersion, shows a gradual decrease in frequency.

In all of our work the water-wave travel time has been used to give the distance to the shotpoint, assuming the speed of sound in water derived from the temperature and salinity of the water. The water wave has always been readily distinguished by its high-frequency character and, at short or moderate distances by its high amplitude. In the time-distance curves the unit of distance is usually taken, for the sake of convenience, as the distance sound travels through water in one second, so that all water-wave arrivals would plot on a line whose slope is unity.

In Figure 2 the ground waves arrive ahead of the water waves and plot on a line through the origin whose slope indicates a sound velocity 5,900/4,925 times

[3] J. M. Ide, R. F. Post, and W. S. Fry, "The Propagation of Underwater Sound at Low Frequencies as a Function of the Acoustic Properties of the Bottom," Naval Research Laboratory Report S-2113(August, 1943).

[4] K. T. Adams, *Hydrographic Manual*, Special Publication No. 143, U. S. Coast and Geodetic Survey (1946), p. 571.

[5] F. L. Peacock, Season's Report, U. S. Coast and Geodetic Survey Archives, Project No. 248, Gulf of Maine (1940), 15 pages.

[6] H. W. Murray, "Topography of the Gulf of Maine—Field Season 1940," *Bulletin Geological Society of America, 58* (1947), 153–196.

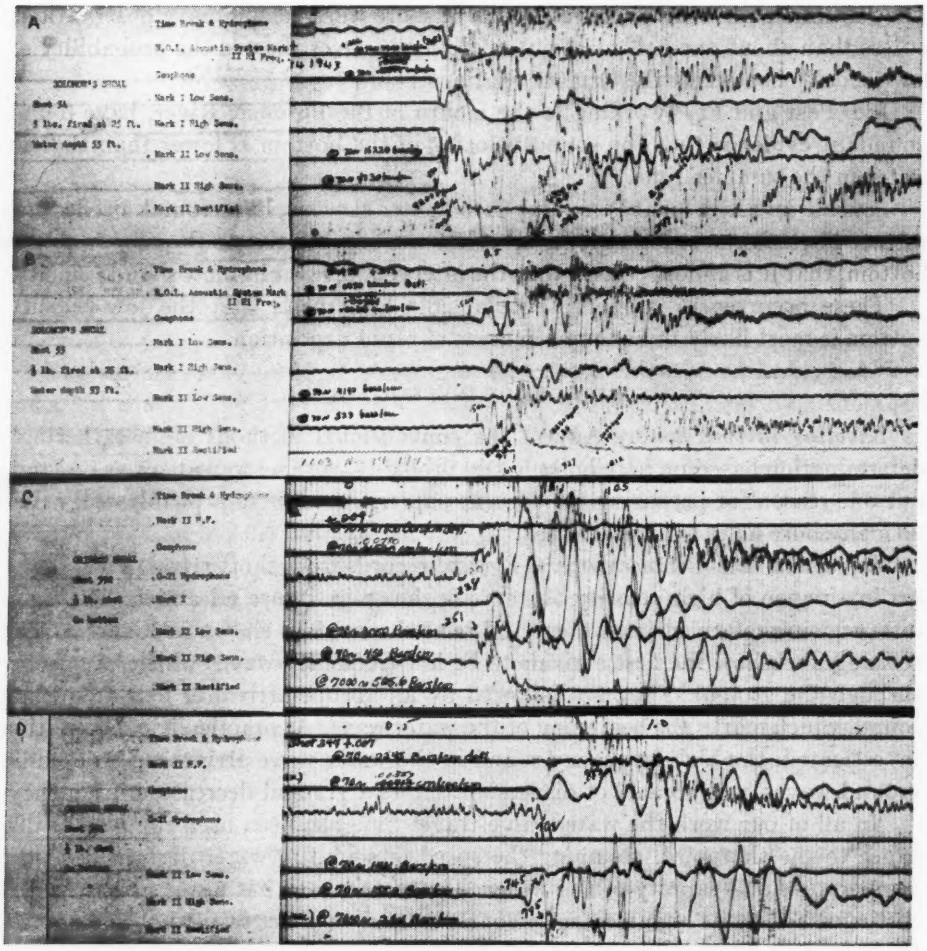
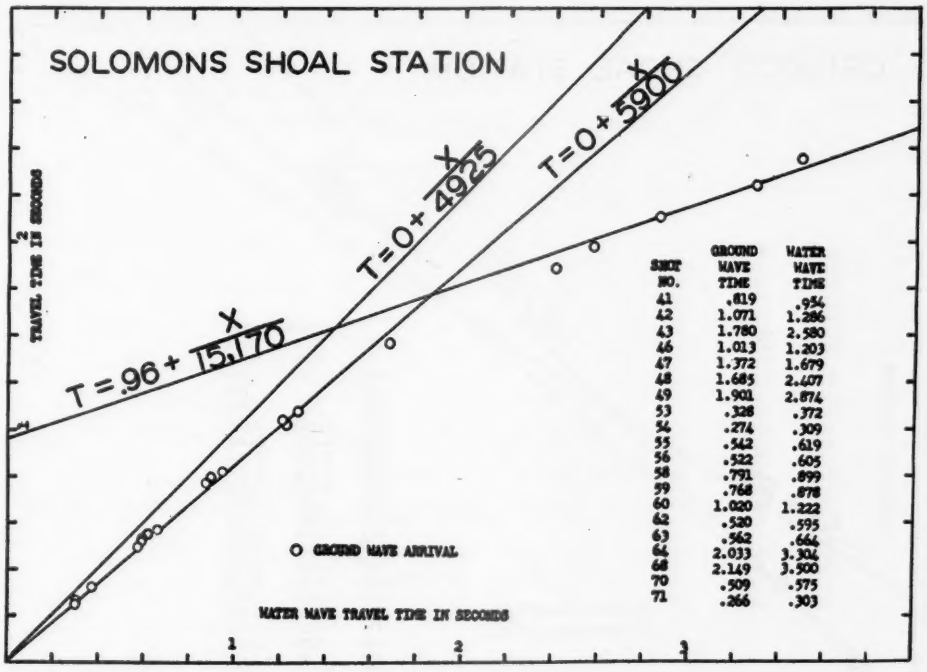


FIG. 1. Typical records from short refraction shots at sea in a region of high-velocity bottom (*A* and *B*) and in a region of low-velocity bottom (*C* and *D*).

greater than that in water. Such data are conclusive evidence that the velocity of sound in the bottom is greater than that in the water by the amount indicated. In all cases where this type of time-distance curve has been found, the dispersion in the water wave gives concordant information about the bottom.

In Figure 1, *C* and *D* are typical records from short-refraction shots at sea in a region of low-velocity bottom. The time-distance curve for these and the related shots is shown in Figure 3. The seismograms show the first arrival to be high-frequency sound for record *C*, which is at the shortest distance. For longer shots, as typified by record *D*, the low-frequency ground waves arrive first, but they plot on a line which passes well above the origin, with an intercept of 0.09 sec.

On the basis of the standard theory[7] for interpretation of refraction profiles, the presence of the intercept and the absence of a ground-wave arrival on record *C* indicate that the first layer of the ocean bed has a sound velocity less than that of water. Study of the relative amplitudes in the four records of Figure 1 leaves little hope that the arrival of a ground wave, similar to the first arrival of *A* and *B*, could be identified if it arrived shortly after the water wave. On the basis of the



SHOT NO.	GROUND WAVE TIME	WATER WAVE TIME
41	.819	.954
42	1.071	1.286
43	1.780	2.580
46	1.013	1.203
47	1.372	1.679
48	1.685	2.407
49	1.901	2.874
53	.328	.372
54	.274	.309
55	.542	.619
56	.522	.605
58	.791	.899
59	.768	.878
60	1.020	1.222
62	.520	.595
63	.562	.666
64	2.033	3.304
68	2.149	3.500
70	.509	.575
71	.266	.303

FIG. 2. Typical time-distance curve in a region of high-velocity bottom.

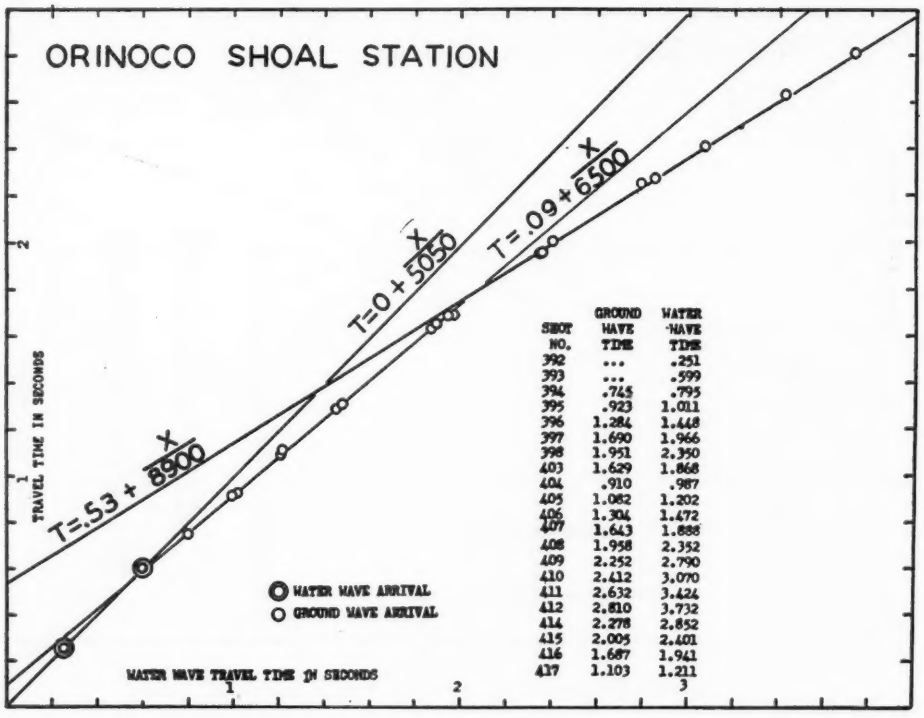
standard theory, if the ground waves in Figure 3 corresponding to the low-velocity layers could be identified, the thickness H of this layer would be given by

$$H = V_2 T_3 / 2 \cos \alpha \qquad (1)$$

where V_2 is the velocity of sound in the second layer (first layer of the bottom), $\alpha = \sin^{-1} V_2/V_3$ with V_3 the velocity of the third layer (second layer of the bottom), and T_3 the intercept of the V_3-branch of the travel-time curve. Thus the depth can be computed only if the velocity V_2 is known from some independent measurement.

[7] See for instance: Maurice Ewing, G. P. Woollard, and A. C. Vine, "Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain, Part III: Barnegat Bay, New Jersey, Section," *Bull. Geol. Soc. of Amer.*, 50 (1939), 257–296.

The standard interpretation has been that the water waves are of high frequency because the water is a superior elastic medium which passes all frequencies well. The low frequency of the ground waves has been explained on the basis of imperfections in the elasticity of the earth, which discriminated strongly against the high frequencies through absorption. The contrast between this view and that based on the normal-mode theory will be pointed out in a later section.



SHOT NO.	GROUND WAVE TIME	WATER WAVE TIME
392	...	.251
393	...	.599
394	.745	.795
395	.923	1.011
396	1.284	1.448
397	1.690	1.966
398	1.951	2.350
403	1.629	1.868
404	.910	.987
405	1.082	1.202
406	1.304	1.472
407	1.643	1.888
408	1.958	2.352
409	2.252	2.790
410	2.412	3.070
411	2.632	3.424
412	2.810	3.732
414	2.278	2.852
415	2.005	2.401
416	1.687	1.941
417	1.103	1.211

FIG. 3. Typical time-distance curve in a region of low-velocity bottom.

Soundings.—Examples of localities in which a fathometer receives an echo from some surface beneath the bottom have been reported by several investigators, for example, Adams[8] (1946). Murray[9] (1947) gives many beautiful examples in the Gulf of Maine of the dual bottom feature, mainly in depressions (Fig. 4). He attributes this to sedimentation on an older surface, and states that in many cases the reflection from the first bottom was much weaker than that from the second. He states further that the sedimentation areas are generally found in basins at depths greater than about 80 fathoms and that the sediment ranges in thickness

[8] *Op. cit.*, p. 571.
[9] *Loc. cit.*

from a thin film up to about 90 feet. There is no evidence in the fathometer readings alone whether the velocity in the sediment is greater or less than that in water, only that the reflection coefficient at the water-sediment interface is small compared to that between the sediment and the older surface which is presumably the crystalline basement.

A. P. Crary, in a personal communication, has reported that in 1942, using a

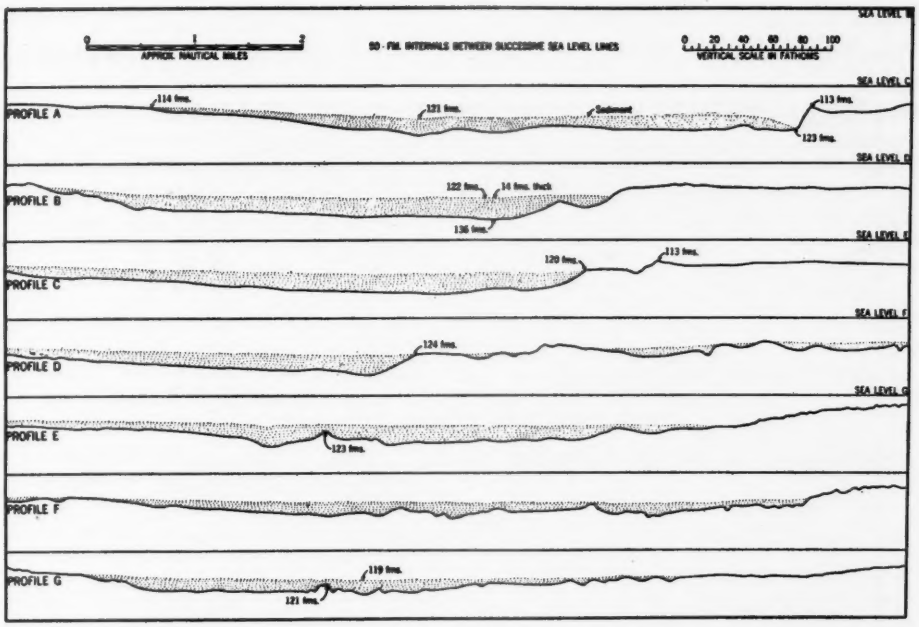


FIG. 4. Composite tracings of Hughes Veselekari fathograms crossing Rodger Basin, Gulf of Maine. (U. S. Coast & Geodetic Survey.)

fathometer in the mouths of the Mississippi River, he noted a second bottom at a depth of some 70 fathoms.

It is of some interest to note that if s_2 is the travel time indicated by the fathometer or other method for vertical travel from the ocean bottom to the reflecting lower surface, then we may put $2H = V_2 s_2$ into (1), obtaining the values V_2 and H from

$$\begin{aligned} s_2 &= T_3/\cos\alpha, \\ H &= V_2 s_2/2. \end{aligned} \tag{2}$$

Thus if s_2 is measured with a fathometer or by vertical seismic reflections, and V_3 and T_3 are measured from a refraction profile, H and V_2 may be calculated. The precision of this measurement of V_2 would be low because it involves the difference $(s_2^2 - T_3^2)$, a small quantity.

Calculation of the relative intensities of sounds reflected at normal incidence from the dual bottoms yields results which may provide geological conclusions of some interest.

From Rayleigh[10] the ratio R of reflected to incident amplitude for normal incidence at the interface between two liquids of densities ρ_1 and ρ_2 and sound velocities V_1 and V_2 is

$$R = (\rho_2/\rho_1 - V_1/V_2)(\rho_2/\rho_1 + V_1/V_2)^{-1}. \tag{3}$$

It may be noted that the absolute value of the reflection coefficient at a given in-

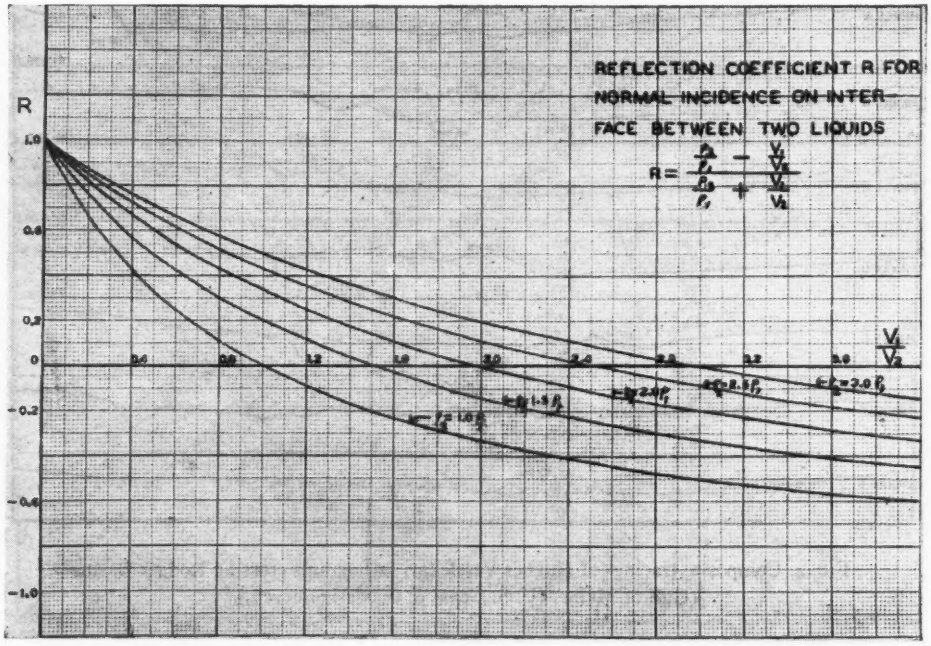


FIG. 5. Reflection coefficient R for normal incidence on interface between two liquids plotted as a function of velocity contrast for various density ratios.

terface for normal incidence is unchanged when the direction of approach is reversed.

Figure 5 is a plot of reflection coefficient as a function of velocity contrast for various densities. On the supposition that ρ_2/ρ_1, is between 1.0 and 3.0 at the bottom, it is seen from the graph that R can be small only when V_1/V_2 is of the same order of magnitude, which indicates a low velocity bottom ($V_1 > V_2$). The large reflections from the lower interface observed by Murray therefore point strongly to a layer of mud, whose velocity is less than that of water, underlain by crystal-

[10] Lord Rayleigh, *Theory of Sound*, II, Macmillan, 1926, 82.

line rock whose velocity is several times greater. This discussion is valid only for wave lengths small compared with the thickness of the layer.

Dispersion in water waves from explosions—High-velocity bottom.—Pekeris[11] has given the theory of normal-mode propagation for two and three liquid layers of

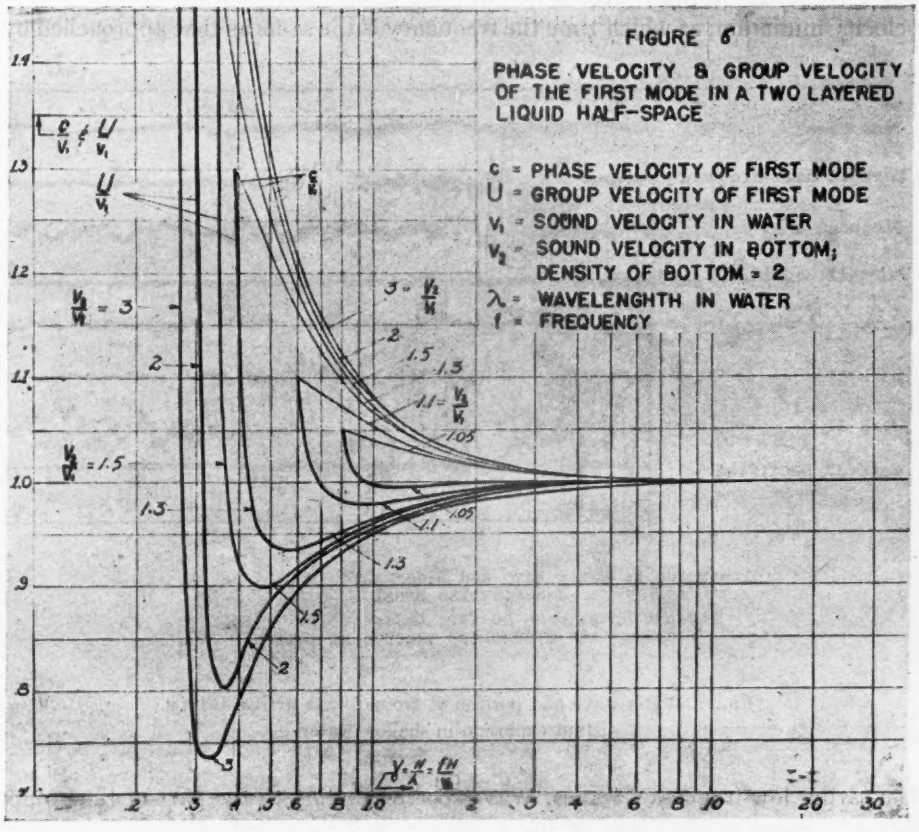


FIGURE 6
PHASE VELOCITY & GROUP VELOCITY OF THE FIRST MODE IN A TWO LAYERED LIQUID HALF-SPACE
c = PHASE VELOCITY OF FIRST MODE
U = GROUP VELOCITY OF FIRST MODE
V1 = SOUND VELOCITY IN WATER
V2 = SOUND VELOCITY IN BOTTOM; DENSITY OF BOTTOM = 2
λ = WAVELENGHTH IN WATER
f = FREQUENCY

FIG. 6. Phase and group-velocity curves for normal-mode sound propagation in two liquid layers. (After Pekeris.)

successfully higher velocity. For the two layer case his results may be summarized by the family of phase-velocity and group-velocity curves plotted in Figure 6, with the acoustic properties of the layers as parameters.

A typical sequence of signals received from a distant explosion in shallow water is shown in Figure 7. This may be explained by referring to any one of the group-velocity curves of Figure 6. The first arrivals, corresponding to the extreme left end of the group-velocity curve, are low-frequency waves which have

[11] C. L. Pekeris, *Memoir 27, Geological Society of America* (in press).

travelled through the ground with velocity V_2. These are followed by waves with slowly increasing frequency which are abruptly interrupted by high-frequency waves, which arrive at the time corresponding to a velocity V_1. These high frequencies correspond to the extreme right-hand end of the group-velocity curve. Their frequency rapidly decreases until the time corresponding to the group-velocity minimum, at which time the frequency is the same as that approached by

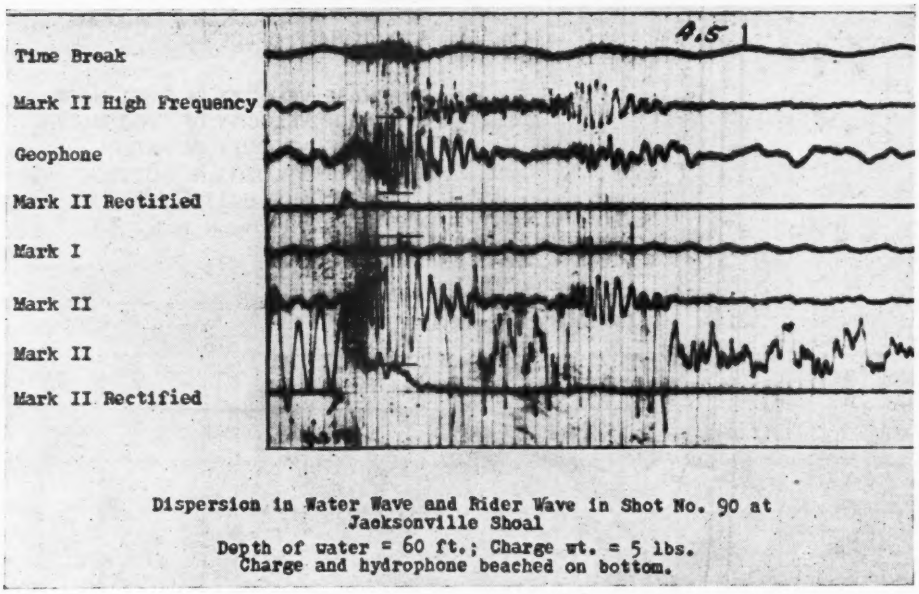

0.5
Time Break
Mark II High Frequency
Geophone
Mark II Rectified
Mark I
Mark II
Mark II
Mark II Rectified
Dispersion in Water Wave and Rider Wave in Shot No. 90 at Jacksonville Shoal
Depth of water = 60 ft.; Charge wt. = 5 lbs.
Charge and hydrophone beached on bottom.

FIG. 7. Water-wave and portion of ground-wave arrival from a distant explosion in shallow water.

the earlier low-frequency waves. Waves corresponding to the part of the group-velocity curve to the right of the minimum will be called water waves, those corresponding to the left part of the curve will be called ground waves. These distinctions strictly apply only to the two ends of the group-velocity curve, and ground transmission gradually changes into water transmission at the minimum. Pekeris has named the frequency corresponding to the minimum of group velocity the Airy frequency and this part of the seismogram the Airy phase.

The Airy phase is characterized by large amplitudes which become the most prominent features of the seismograms at greater distances. The earlier part of the seismogram is usually affected by arrivals which have travelled through deeper, higher-speed layers. Thus the simple two-layer theory given above usually applies only to that part of the seismogram fairly near the water-wave arrivals, but the theory will account for that part of the seismogram in great detail.

In Pekeris' three-layer theory, the water waves behave much as they do for

the two-layer case, provided the second layer is several times thicker than the first.

Dispersion in water waves from explosions—Low-velocity bottom.—Calculations have been made for the phase and group velocity in case the bottom is composed of a low-velocity layer, $V_2 < V_1$ underlain by a high-velocity layer, $V_3 > V_1$. These curves are shown in Figure 8 to consist of two branches. The first is much like

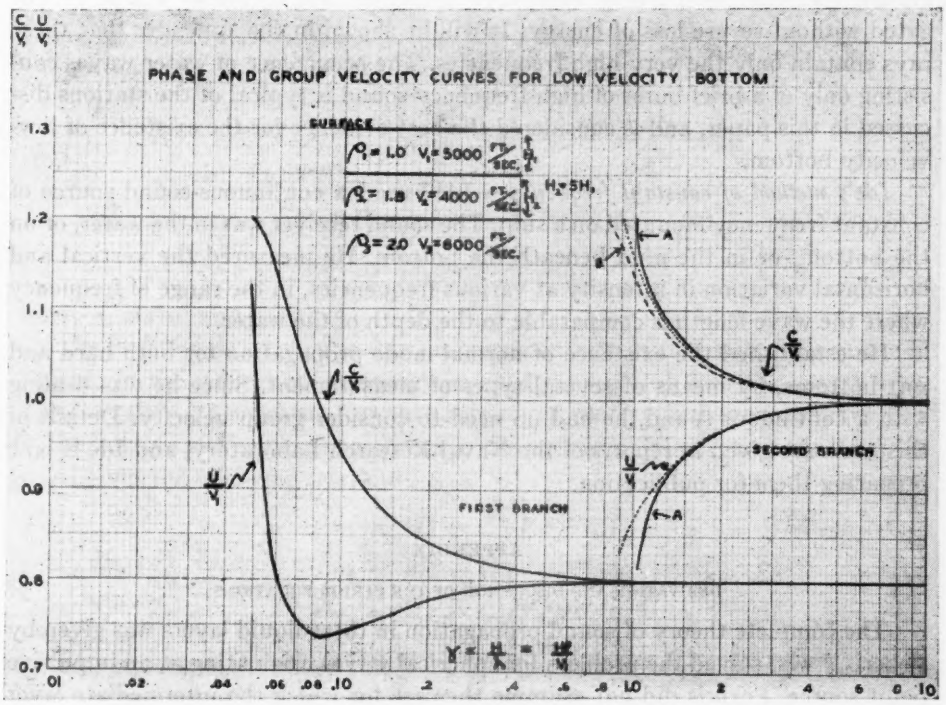


FIG. 8. Phase and group-velocity curves for normal-mode sound propagation in three liquid layers. The intermediate layer represents the low-velocity bottom.

those of Figure 6 and can be discussed in a similar manner. The high frequencies should now arrive with a velocity V_2 appropriate to the low-speed layer instead of travelling with the speed of sound in water. At the time corresponding to the group velocity $U = V_3$, the waves arrive with the cutoff frequency. At the time corresponding to the minimum-group velocity, the Airy phase should arrive, and it should be the most prominent phase on the record. However, only that part of the group-velocity curve to the left of the minimum has as yet been observed. The failure to find the high-frequency part of the signal, and the Airy phase, travelling with velocities in the neighborhood of that for mud, is attributed to absorption phenomena in the mud, and possibly to stratification in the mud.

The second branch, in Figure 8, consists of two parts, A and B, and is dis-

tinguished by the absence of a minimum-group velocity. High-frequency waves will arrive with the velocity of sound in water. The lower frequencies will be highly attenuated because of loss of energy into the bottom. Branch II represents a type of propagation which is essentially characterized by multiple reflections in the water layer. The reflection coefficient for a ray incident on a low-velocity bottom increases with the angle of incidence. It approaches total reflection for grazing incidence, hence only those rays having grazing incidence will be propagated without severe loss of energy. It will be shown in the appendix that these rays contain only the very high frequencies. The occurrence of water waves consisting only of a brief burst of high-frequency sound is typical of the stations discussed in this paper, and is considered the best evidence for the existence of low-velocity bottom.

Ide's method of constant frequency.—Ide[12] used a continuous-sound source of constant frequency mounted on a ship. The sound receiver was in the water, or on the bottom, or in the mud beneath the bottom. He measured the vertical and horizontal variation in intensity at various frequencies, in the range of frequency where the wave length is comparable to the depth of the water.

He established the existence of normal-mode propagation for both hard and soft bottoms, by means of several types of measurement. Since he was dealing with a continuous sound, he had no need to consider group velocity. Details of this work are given in reports of the Naval Research Laboratory, and Ide is now preparing them for publication.

APPENDIX

DERIVATION AND DISCUSSION OF THE PERIOD EQUATIONS

The complete theory of sound propagation in three liquid layers was given by Pekeris,[13] who solved the problem for spherical waves originating at an impulsive point source. Pekeris did not examine the case for which the intermediate layer has a lower sound velocity than the first layer. The complete solution for the case of a low-velocity bottom can be obtained from the Pekeris theory, but it is sufficient for our purposes to discuss the solution for plane waves. The plane-wave solution results in the identical period equation given by Pekeris, and has the added advantage of giving an elementary picture of normal-mode propagation. For a rigorous derivation of the amplitudes and periods of sound waves originating in shallow-water explosions, one must use the methods of Pekeris.

Let us consider the propagation of plane sound waves in three liquid layers having densities ρ_1, ρ_2, ρ_3, sound velocities V_1, V_2, V_3, and thicknesses h_1, h_2, and ∞, respectively. The cartesian coordinate system is chosen so that the xy-plane lies in the free surface, with x oriented in the direction of propagation, and the z-axis vertically downward. We introduce the sound potential $\phi(x, z, t)$ related to

[12] *Loc. cit.*

[13] *Loc. cit.*

the pressure p and the horizontal and vertical particle velocities u and w by the equations:

$$p = \rho\partial\phi/\partial t, \qquad u = \partial\phi/\phi x, \qquad w = \partial\phi/\phi z. \tag{1}$$

It is required to find functions ϕ_j which satisfy the wave equations

$$\partial^2/\phi_j/\partial t^2 = V_j{}^2\nabla^2\phi_j; \qquad j = 1, 2, 3. \tag{2}$$

It can readily be verified that solutions are of the form:

$$\left.\begin{aligned}
&(a)\quad \phi_1 = A\exp[\eta_1 z]\exp[i(kx-\omega t)] \\
&\qquad\quad + B\exp[-\eta_1 z]\exp[i(kx-\omega t)], \\
&(b)\quad \phi_2 = C\exp[\eta_2 z]\exp[i(kx-\omega t)] \\
&\qquad\quad + D\exp[-\eta_2 z]\exp[i(kx-\omega t)], \\
&(c)\quad \phi_3 = E\exp[-\eta_3 z]\exp[i(kx-\omega t)],
\end{aligned}\right\} \tag{3}$$

where η_3 is real and positive.

The function ϕ_3 is taken to decrease exponentially with depth since we are interested in the case where no energy is lost by refraction into the lowest layer. This is equivalent to postulating that only sound waves which are totally reflected at the lowest interface are considered in the solution. Substituting equations (3) in (2) gives the following relations:

$$\left.\begin{aligned}
\eta_1 &= k(1 - C^2/V_1{}^2)^{1/2}, \\
\eta_2 &= k(1 - C^2/V_2{}^2)^{1/2}, \\
\eta_3 &= k(1 - C^2/V_3{}^2)^{1/2}.
\end{aligned}\right\} \tag{4}$$

In these equations the phase velocity C is related to the wave number k and the angular frequency ω by the equation $C=\omega/k$.

Equations (3) must satisfy boundary conditions which require the continuity of pressure and vertical particle velocity at the liquid interface, and zero pressure at the free surface. Thus we have

$$\left.\begin{aligned}
&\text{at } z = 0, && \rho_1\partial\phi_1/\partial t = 0; \\
&\text{at } z = h_1, && \rho_1\partial\phi_1/\partial t = \rho_2\partial\phi_2/\partial t; \\
& && \partial\phi_1/\partial z = \partial\phi_2/\partial z \\
&\text{at } z = h_1 + h_2, && \rho_2\partial\phi_2/\partial t = \rho_3\partial\phi_3/\partial t, \\
& && \partial\phi_2/\partial z = \partial\phi_3/\partial z.
\end{aligned}\right\} \tag{5}$$

Substituting equations (3) in (5) and eliminating the constants A, B, C, D, E between the resultant expressions yields the period equation:

$$\left.\begin{aligned}&(\rho_1/\rho_2)(1-C^2/V_2^2)^{1/2}(1-C^2/V_1^2)^{-1/2}\tanh\left[kh_1(1-C^2/V_1^2)^{1/2}\right]\\&\quad+\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(1-C^2/V_2^2)^{-1/2}\right.\\&\qquad\left.\cdot\tanh\left[kh_2(1-C^2/V_2^2)^{1/2}\right]+1\right\}\\&\quad\times\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(1-C^2/V_2^2)^{-1/2}\right.\\&\qquad\left.+\tanh\left[kh_2(1-C^2/V_2^2)^{1/2}\right]\right\}^{-1}=0.\end{aligned}\right\}\tag{6}$$

For the low-speed bottom $V_2<V_1<V_3$. It is also required that $C<V_3$ in order for η_3 to be real, and we have therefore the two cases:

$$\text{I:}\quad V_2<C<V_1<V_3,$$
$$\text{II:}\quad V_2<V_1<C<V_3,$$

for which (6) reduces to:

Case I.

$$\left.\begin{aligned}&(\rho_1/\rho_2)(C^2/V_2^2-1)^{1/2}(1-C^2/V_1^2)^{-1/2}\tanh\left[kh_1(1-C^2/V_1^2)^{1/2}\right]\\&\quad+\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(C^2/V_2^2-1)^{-1/2}\right.\\&\qquad\left.\cdot\tan\left[kh_2(C^2/V_2^2-1)^{1/2}\right]+1\right\}\\&\quad\times\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(C^2/V_2^2-1)^{-1/2}\right.\\&\qquad\left.-\tan\left[kh_2(C^2/V_2^2-1)^{1/2}\right]\right\}^{-1}=0.\end{aligned}\right\}\tag{7}$$

Case II.

$$\left.\begin{aligned}&(\rho_1/\rho_2)(C^2/V_2^2-1)^{1/2}(C^2/V_1^2-1)^{-1/2}\tan\left[kh_1(C^2/V_1^2-1)^{1/2}\right]\\&\quad+\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(C^2/V_2^2-1)^{-1/2}\right.\\&\qquad\left.\cdot\tan\left[kh_2(C^2/V_2^2-1)^{1/2}\right]+1\right\}\\&\quad\times\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(C^2/V_2^2-1)^{-1/2}\right.\\&\qquad\left.-\tan\left[kh_2(C^2/V_2^2-1)^{1/2}\right]\right\}^{-1}=0.\end{aligned}\right\}\tag{8}$$

In Figure 9, *ADFGHI* represents the ray path of a plane wave which is reflected at the free surface, refracted into the second layer, and reflected at the interface of the second and third layer. As the wave front (shown by the dashed line) moves a distance $BC=V_1$ in unit time, a point on the wave front moves a distance JK in the horizontal direction, where $JK=C=V_1/\sin\theta_1=V_2/\sin\theta_2$ and C is the phase velocity. In this representation the wave number k is given by $k=(2\pi/\lambda_1)\sin\theta_1=(2\pi/\lambda_2)\sin\theta_2$, where λ_1 and λ_2 are the wave lengths measured along the ray paths in layers 1 and 2 respectively.

In general a fraction of the wave will be reflected each time the ray crosses the intermediate interface. If we denote the reflection coefficients for waves incident upon the interface from above and below by R_{12} and R_{21} respectively, we have from Rayleigh[14]

[14] *Op. cit.*, p. 81.

$$\left.\begin{aligned} R_{12} &= (\rho_2/\rho_1 - \cot\theta_2/\cot\theta_1)(\rho_2/\rho_1 + \cot\theta_2/\cot\theta_1)^{-1}; \\ R_{21} &= (\rho_1/\rho_2 - \cot\theta_1/\cot\theta_2)(\rho_1/\rho_2 + \cot\theta_1/\cot\theta_2)^{-1} = -R_{12}. \end{aligned}\right\} \quad (9)$$

Using the relationships $k(C^2/V_1^2-1)^{1/2}=(2\pi/\lambda_1)\cos\theta_1$, and $k(C_2^2/V_2^2-1)^{1/2}=(2\pi/\lambda_2)\cos\theta_2$ the previous equations become

$$\begin{aligned} R_{12} &= [\rho_2/\rho_1 - (C^2/V_2^2 - 1)^{1/2}(C^2/V_1^2 - 1)^{-1/2}] \\ &\quad \cdot [\rho_2/\rho_1 + (C^2/V_2^2 - 1)^{1/2}(C^2/V_1^2 - 1)^{-1/2}]^{-1} \\ &= -R_{21}. \end{aligned} \quad (10)$$

For Case I where $V_2<C<V_1<V_3$, R_{21} becomes complex and reduces to $R_{21}=\exp.\ [-i\psi_{21}]$, where $\tan(\psi_{21}/2)=(\rho_2/\rho_1)\ (1-C^2/V_1^2)^{1/2}\ (C^2/V_2^2-1)^{-1/2}$. The complex reflection coefficient indicates that total reflection with a phase change of $-\psi_{21}$ occurs for a ray incident on the first layer from below. Case I therefore represents a type of propagation in which the rays are confined to the low-velocity layer because of total reflection at the boundaries of this layer.

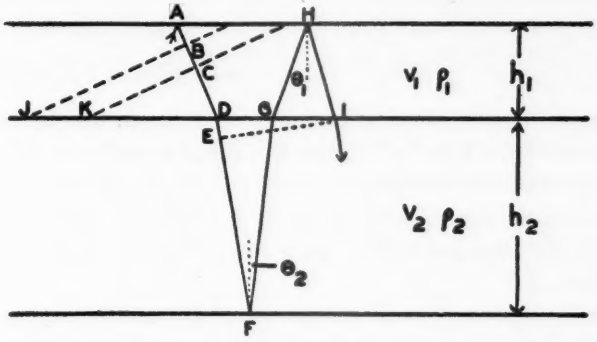


FIG. 9. Ray diagram of normal-mode sound propagation for the case of a low-velocity bottom.

In Case II the rays are confined to the first two layers due to total reflection at the free surface with a phase change of $-\pi$, and total reflection at the lowest interface with a phase change of $-\psi_{23}$ where $\tan(\psi_{23}/2)=(\rho_2/\rho_3)\ (1-C^2/V_3^2)^{1/2}\cdot(C^2/V_2^2-1)^{-1/2}$.

The period equation for sound propagation in two or three liquid layers is simply the condition for constructive interference between the rays which are multiply reflected at the various boundaries. This can be readily shown when $R_{12}=0$ or $(\rho_2/\rho_1)\ (C^2/V_1^2-1)^{1/2}\ (C^2/V_2^2-1)^{-1/2}=1$, that is, for the case when no partial reflection occurs at the interface between the first and second layers (Fig. 9).

If the wave front *EI* is to interfere constructively with the coincident wave front which has traversed the additional path *EFGHI*, it is required that:

$$(2\pi/\lambda_2)EFG - \psi_{23} + (2\pi/\lambda_1)GHI - \pi = 2(n-1)\pi \quad n = 1, 2, 3, \cdots \quad (11)$$

where $-\psi_{23}$ and $-\pi$ are the phase changes that occur at the lowest interface and free surface respectively. From the geometry of Figure 9 we note that:

$$GHI = 2h_1/\cos\theta_1;$$
$$EFG = 2h_2/\cos\theta_2 - (2h_2 \tan\theta_2 + 2h_1 \tan\theta_1)\sin\theta_2.$$

Substituting for GHI and EFG and using $\lambda_2/\lambda_1 = \sin\theta_1/\sin\theta_2$, equation (11) becomes:

$$(2\pi/\lambda_1)h_1 \cos\theta_1 = -(2\pi/\lambda_2)h_2 \cos\theta_2 + \psi_{23}/2 + (2n-1)\pi/2. \qquad (12)$$

Now

$$(2\pi/\lambda_1)\cos\theta_1 = k(C^2/V_1^2 - 1)^{1/2}, \qquad (2\pi/\lambda_2)\cos\theta_2 = k(C^2/V_2^2 - 1)^{1/2},$$
$$\tan(\psi_{23}/2) = (\rho_2/\rho_3)(1 - C^2/V_3^2)^{1/2}(C^2/V_2^2 - 1)^{-1/2}.$$

If we take the tangent of both sides of (12) and make these substitutions, the following equation is obtained:

$$\tan\left[kh_1(C^2/V_1^2-1)^{1/2}\right]$$
$$= -\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(C^2/V_2^2-1)^{-1/2}\tan\left[kh_2(C^2/V_2^2-1)^{1/2}\right]+1\right\}, \qquad (13)$$
$$\times\left\{(\rho_2/\rho_3)(1-C^2/V_3^2)^{1/2}(C^2/V_2^2-1)^{-1/2}-\tan\left[kh_2(C^2/V_2^2-1)^{1/2}\right]\right\}^{-1}.$$

This is the same as the period equation for Case II except for the amplitude factor $(\rho_1/\rho_2)(C^2/V_2^2-1)^{1/2}(C^2/V_1^2-1)^{-1/2}$, which is equal to unity for $R_{12}=0$. In general when $R_{12}\neq 0$, the amplitude factor enters into the period equation which represents the condition for constructive interference between three or more rays having different amplitudes depending upon the reflection coefficient at the intermediate interface.

The period equations (7) and (8) give the frequency $f=\omega/2\pi=Ck/2\pi$ as a function of the phase velocity with the dimensions and acoustic properties of the system as parameters. The equations cannot be solved explicitly for the frequency which must be determined by numerical calculations. It is found that the frequency is a multiple-valued function of the phase velocity, each value belonging to the various modes of two distinct branches. Each branch of the period equation corresponds to a different type of wave propagation.

The numerical calculations of the branches are simplified by making several changes in variables. We let $h_2=5h_1$ and

$$e = (\rho_2/\rho_3)(1 - C^2/V_3^2)^{1/2}(C^2/V_2^2 - 1)^{-1/2}, \quad a = (1 - C^2/V_1^2)^{1/2} \text{ for Case I,}$$
$$b = 5(C^2/V_2^2 - 1)^{1/2}, \quad a = (C^2/V_1^2 - 1)^{1/2} \text{ for Case II,}$$
$$\Phi = kh_1a, \quad f = (\rho_1/a\rho_2)(C^2/V_2^2 - 1)^{1/2}.$$

With these substitutions, equations (7) and (8) become:

Case I.

$$\tanh\Phi = \{e\tan[(b/a)\Phi] + 1\}\{f[\tan[(b/a)\Phi] - e]\}^{-1}. \qquad (14)$$

Case II.

$$\tan \Phi = \{e \tan [(b/a)\Phi] + 1\}\{f[\tan [(b/a)\Phi] - e]\}^{-1}. \qquad (15)$$

The numerical procedure is to choose a value of C/V_1, thus determining a, b, e, and f. Approximate values of Φ which satisfy (14) or (15) are obtained by successive trials. The correct value of Φ is obtained from the intersection of the graphs of the right and left sides of the period equation plotted as functions of Φ. Using the relationship $kh_1 = \Phi/a$, kh_1 and $\gamma = h_1/\lambda_1 = (kh_1C)/(2\pi V_1)$ are readily obtained. The group velocity $U = C + (kh_1)dC/d(kh_1)$ is determined by numerical differentiation.

The phase and group velocities of the first and second branches have been plotted as functions of γ in Figure 8. Branch I is obtained by calculating the smallest values of Φ which satisfy equations (14) and (15) for a chosen sequence of values of C/V_1. Higher modes of Branch I, representing transmission at higher frequencies, can be obtained by taking successively larger roots for the given sequence of (C/V_1) values. For all modes of Branch I, however, $\Phi \to o$ as $C \to V_1$, in such a manner that $\Phi/a = kh_1$ remains finite. It can be seen from equations (7) and (8) that for the first branch, Case I grades continuously into Case II as C goes through V_1 (the first term in both equations approaches the same limit as $C \to V_1$).

The type of propagation represented by the first branch is now apparent. As C goes from V_3 to V_1 (Case II), the energy is distributed in the first two layers as multiply reflected rays which interfere constructively with each other. As $C \to V_1$, or as the frequency increases, the energy is drawn into the low-speed layer. For $C < V_1$ (Case I) the propagation consists of multiply reflected rays confined to the low-speed layer. The energy for this case is concentrated in the low-speed layer and falls off exponentially with distance from the boundaries of this layer. If equation (3a) is substituted in the first boundary condition, it is found that $A = -B$, and $\phi_1 = 2a \sinh (\eta_1 z) \exp [i(kx - \omega t)]$. From equation (4) it is seen that the rates, η_1 and η_3, at which the velocity potentials ϕ_1 and ϕ_3 decrease with distance from the boundaries of the low-speed layer, increase as C approaches V_2 or as the frequency increases.

Branch II consists of two parts, A and B, both of which are obtained from equation (15) (Case II) by determining the values of Φ corresponding to a given sequence of values C/V_1, such that $\Phi \to \pi$ as $C \to V_1$. In Branch IIA $\Phi \geqq \pi$ whereas $\Phi \leqq \pi$ for Branch IIB. Branch II represents a type of propagation for which the rays are confined to the first two layers. However, the functional dependence of phase and group velocity on frequency is essentially determined by propagation in the first layer. This can be seen by writing down the condition for constructive interference of rays confined to the first layer because of total reflection with a phase change of $-\pi$ at the free surface and partial reflection at the intermediate interface.

$$(2\pi/\lambda_1)h_1 \cos \theta_1 - \pi = 2(n-1)\pi \quad n = 1, 2, 3, \cdots . \qquad (16)$$

We also have $C = V_1/\sin\theta_1$ and from (16)

$$U = C - \lambda dc/d\lambda = V_1 \sin\theta_1. \tag{17}$$

A plot of C/V_1 and U/V_1 as functions of γ based on the previous equations is shown by the dotted curve of Figure 8. The close fit with Branch II, especially for higher frequencies, is apparent.

The rays confined to the first layer will in general have small amplitudes because of partial refraction into the second layer at each reflection from the intermediate interface. With increasing angles of incidence corresponding to decreasing C or increasing f, the reflection coefficient R_{12} increases in absolute value and approaches unity for grazing incidence. The energy of the waves represented by the second branch is therefore drawn into the first layer with increasing frequency. It is to be expected, therefore, that a signal propagated according to the second branch would appear as a high frequency burst arriving with a velocity $U = V_1$. The lower-frequency arrivals would not be observed because of their small amplitudes. This characteristic arrival pattern has been observed and is described in an earlier section.

EXPLOSIVES ACCIDENTS ON GEOPHYSICAL CREWS*

P. M. HANAHEN†

ABSTRACT

This paper discusses accidents caused by the improper handling of explosives by geophysical crews.

Since the war, geophysical companies have been experimenting with the use of aluminum loading poles. Premature ignitions have been caused by the electric current generated by the galvanic cell formed by the aluminum loading poles, the alkaline mud, and the steel casing of the shot hole. This paper gives a brief description of tests that have been made on the amount of electric current generated by such a cell.

Static electricity has been blamed for the ignition of detonators while the primer was being prepared. This paper briefly summarizes the experiments conducted by the Bureau of Mines and discussed in *Report of Investigations 3852* "Sensitivity of Explosive to Initiation by Electrostatic Discharges" and the probabilities that static electricity caused premature detonations.

From the data discussed in this paper, the author concludes that there is a need for establishing a set of standard safety regulations in the geophysical industry, and that before any new piece of equipment, such as aluminum loading poles, is introduced, the problem should be studied to insure that a new hazard is not introduced. Only a safe geophysical crew operates economically and efficiently, and, in order to promote and maintain efficient operations, geophysical companies must not revert to the unsafe practices used prior to the war.

INTRODUCTION

Shortage of manpower and equipment during the war taught many industries, including the geophysical industry, that safe operations and procedures are a *must*. Every geophysical party chief has learned that an accident can result not only in destroyed equipment but also in the loss of valuable personnel and time.

Because of the wide range of activities and the various types of equipment and materials handled, the geophysical industry must be prepared to cope with practically every type of hazard. Experience obtained during the war shows that it is practically a necessity that a standard set of safety instructions be compiled and used throughout the industry. This would be especially beneficial when personnel is exchanged between companies and between parties within a company.

LOCATION OF HOLE

The safe shooting of a hole starts before the arrival of the drill. When selecting a location, the surveyor should consider the proximity of the hole to public highways, buildings, and above all, to power lines.

STORAGE AND TRANSPORTATION OF EXPLOSIVES

The condition of the explosive is important for safe and efficient shooting. During the war it was essential that explosives be stored in theft-proof magazines.

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Such storage protected the explosives from deterioration; as a result, relatively few accidents or misfires resulted from deteriorated explosives. Since the war, some companies have failed to provide the proper type of storage for explosives. It is believed that some of the misfires were caused by improper storage and some of the recent ones by the condition of the explosives. Explosives containing components that are affected by water should not be allowed to remain in water or be exposed to it for an extended period. A high hydrostatic head affects many explosives.

During the war period, particular attention was paid to the construction of shooting trucks, especially to the explosives magazines or containers in which the explosives and detonators were transported. Then and now the operation of geophysical trucks on the highways is under the supervision of the Interstate Commerce Commission. The regulations of the Interstate Commerce Commission still require proper maintenance of the trucks on the highways.

The Texas City disaster has made many people explosion-conscious; as a result, regulatory bodies in many villages along the bayous and waterways have become cognizant of the hazards presented by geophysical parties handling explosives by boat.

SMOKING REGULATIONS

Had no-smoking regulations been enforced on the S. S. *Grandcamp*, one possible cause of the Texas City disaster would have been removed. A current magazine article on geophysics was illustrated with recent pictures of a shooting crew removing explosives from the truck magazine, making up the priming charge, and loading the hole. In each picture the members of the crew had cigarettes in their mouths. This indicates that some geophysical crews are not complying with safe explosives practices.

LIQUEFIED-PETROLEUM GAS ON GEOPHYSICAL BOATS

Liquefied-petroleum gas is being used on many geophysical boats for heating and cooking. If a leak occurs in the liquefied-petroleum gas line aboard the boat, the gas, which has a specific gravity of approximately 2, will tend to accumulate in the low areas or confined unventilated spaces.

When liquefied-petroleum gas storage tanks are placed on the deck, the lines from the tanks extend below deck to the galley and the appliances are used below deck. Propane, one of the liquefied-petroleum gases, condenses at approximately -44°F.; thus, there is little hazard of its condensing during cold weather. If normal butane, which condenses at approximately 32°F., is used during cold weather, liquid may form in the lines and flow out of the burners when the appliance valves are opened. If butane is used, the lines should extend from the storage tanks directly to a vaporizer located lower than the lowest outlet. All liquefied-petroleum gas lines should be installed so that they drain back to the vaporizer and so that liquid will not be trapped in bends or low places in the line. Because of their vapor pressures, butane can be stored or used in a tank and sys-

tem designed for propane, but propane should not be stored or used in a tank designed for butane.

RÉSUMÉ OF REPORTED ACCIDENTS

The following is a brief outline of the explosives accidents reported to the Dallas office of the Bureau of Mines prior to May 1945.[1]

"One crew member was very seriously injured because a charge detonated prematurely, probably due to static electricity which had collected on 60-foot lead wires during a thunderstorm.

"Two men were injured when they endeavored to force past an obstacle in the hole a ½-pound charge of explosives containing a detonator.

"One man was seriously injured when the tools of a loading machine, which was being used to knock out a bridge in a hole struck and detonated explosives in the bottom of the hole, under 30 feet of water.

"One man was very seriously injured by the explosion of a detonator he was holding while he attempted to jerk loose the leg wires which had become entangled in a bush as he was preparing to make up a charge.

"Two members were injured when they reloaded a hole immediately after it had been shot and the heat detonated the explosives.

"One member was killed and one was seriously injured because the wrong wires were connected and a charge on the surface detonated instead of the one in the hole.

"Four geophysical-crew members lost their lives because of shooting near power lines.

"A farm boy was injured while dissecting a detonator that he had pulled from a hole left loaded overnight."[2]

Since 1945 only a few geophysical companies have sent the Bureau of Mines a copy of the reports of their explosives accidents.

ALUMINUM LOADING POLES

Recently the Bureau of Mines has received reports of premature ignitions caused by the electric current generated when aluminum loading poles were being used in a cased hole. The Research Division of The Carter Oil Company became interested in the premature detonations caused by the use of aluminum loading poles, and J. F. Bayhi of that company made a laboratory study to determine the extent of the hazards involved in the use of the poles.

Bayhi first determined the current required to fire the detonators commonly used in seismograph work. The voltage applied to the detonator was slowly raised and both the current and voltage were recorded until the firing point was reached.

[1] G. M. Kintz, "Informal Discussion of Explosives Hazards on Seismograph Crews," *Geophysics*, XI (1946), 148–163.

[2] *Ibid.*, p. 149.

The results for the four types of detonators tested are as follows:

Type Caps	Minimum Firing current (amps)	Resistance of Cap ohms (hot)	Resistance of Leads* ohms/ft.
DuPont SSS6	.29	2.01	0.01
Hercules	.32	1.04	0.01
DuPont SSS8	.40	1.35	0.01
Atlas "B"	.50	1.50	0.01

* AWG Size-20 copper wire generally used for cap leads.[3]

Since these values are the lowest obtained in five tests of each type of detonator and the deviation from the mean was not over 5 percent, it seems that manufacturing tolerances for caps are fairly close.

The following concerning aluminum-iron cell potentials is quoted from Bayhi's report:

"The next question which arises is, 'What voltage exists between aluminum and iron in mud solutions similar to those encountered in seismograph shot hole drilling?' As a guide to the magnitude of potentials to be expected from such a cell, the following extract from the 'Electromotive Force Series of Elements' provides these Standard Electrode Potentials at 25°C.

Element	Electrode Potentials*
Al	+1.70 Volts
Fe	+0.44 Volts
H_2	0.00 Volts

* Ions are assumed to be present in a 1 molar concentration.

"This indicates that a potential of about 1.26 volts exists between aluminum and iron when sufficient ions are present in solution. The potential of aluminum in various solutions is discussed in some detail on pages 114 and 115 of the publication 'Corrosion' for September, 1945. A summary of this discussion indicates that the potential of aluminum is generally lower in neutral or acid solutions than in alkaline solutions. The reason is probably that aluminum rapidly coats itself with a protective oxide (or other) film upon exposure to many solutions. In alkaline solutions this protective film is not stable, so that the aluminum remains active. The possibility of the copper cap lead wires acting as an electrode against the iron or aluminum was considered. Copper has an electrode potential of plus 0.33 volt, a value which does not allow sufficient voltage against iron to be considered as a problem. This value against aluminum, 1.37 volts, is high enough to be dangerous. But on the other hand, even a liberal estimation of the area of copper exposed by faulty insulation to the solution would not provide enough for a current capacity sufficient to fire a cap."[4]

[3] J. F. Bayhi, *Premature Explosions Caused by Use of Aluminum Tamp Rods in Cased Seismograph Shot Holes*, The Carter Oil Company, August 1, 1947.

[4] Bayhi, *op. cit.*, pp. 2–3.

Bayhi describes the laboratory measurements on an aluminum-iron cell as follows:

"It was decided to construct an aluminum-iron cell in the laboratory with various conditions of drilling muds as electrolytes, and to measure the voltage and currents obtained from such a cell. In order to duplicate field conditions as closely as possible, the cell was set up using a 2-foot section of an aluminum tamp rod (grade 24-S-T "duraluminum") and a section of 6-inch steel casing closed on one end to hold fluids. The casing was filled with drilling mud and the one inch diameter aluminum rod inserted to a depth of about 18 inches. The drilling mud used was a typical clay based mud from Garvin County, Oklahoma, having about 2–4% aquagel added. As originally received the mud was in a slightly alkaline condition, having a pH of 8. In order to obtain separate voltage and current measurements under other values of pH, a slight amount of acetic acid was added to one sample which lowered the pH to 6, while a small amount of lye was added to another sample, raising its pH to 11."[5]

The actual firing of several detonators from the test cell proved that when the cell contained alkaline muds there was sufficient energy to fire most of them.

Bayhi further states:

"In the hope of making the use of aluminum rods safer, it was suggested that the rods be anodized and tests made upon the insulation resistance of such an anodic coating in drilling muds. Several sample aluminum rod sections were anodized in a standard 3% chromic acid electrolyte for a period of over an hour at 40 volts. This treatment provided a coating, gray in tint, fairly durable, and about .0002 inch thick. . . . In the highly alkaline mud (pH of 11) only 10 minutes were required to dissolve the anodic coating and increase the current to that equivalent to a bare one. For the slightly alkaline mud (pH of 8) about 75 minutes were required to dissolve the coating. Though the coating seems to remain intact for an indefinite period in the slightly acid mud (pH of 6), the bare rod itself maintained a sufficient coating to prevent high currents in such a mud. The use of anodized rods, therefore, does not appear to be a satisfactory remedy."[6]

The tests proved that the use of aluminum loading poles, or any other equipment that will cause a flow of electric current, may cause a premature ignition and that anodized coatings for aluminum loading poles will last only a few minutes when immersed in mud having high alkaline content.

The problem of making a detonator that cannot be fired by an electric current generated by aluminum loading poles was presented to three manufacturers of explosives. Two companies were unable to undertake the work, but the other is experimenting to develop such a detonator. If a detonator with high internal resistance is developed for use with aluminum loading poles, geophysical parties will have to take additional precautions. They must be sure that they always use the special detonator and that adequate voltage and current are available to fire it.

Consideration has been given to covering the loading pole with an economical,

[5] *Ibid.*, p. 3.

[6] Bayhi, *op. cit.*, pp. 3–4.

impervious, non-conducting material, but no practicable preparation has yet been found.

ACCIDENTS DUE TO STATIC ELECTRICITY

The Dallas office of the Bureau of Mines has received several reports of premature detonations believed to have been caused by static electricity. In June 1947 a severe dust and sand storm reached a climax late in the afternoon. One drill crew reported having observed static charges of sufficient strength to cause a severe shock when they touched the metal on the truck. Late that afternoon the shooter and the helper arrived at the hole and began the usual operations. The shooter took one 60-foot lead-wire detonator out of the truck detonator magazine and went to the vicinity of the hole while the helper was taking the necessary dynamite from the truck magazine. The shooter extended the cap leads by the usual method of throwing them and holding the lead wires near the detonator. The leads had reached the ground and the shooter had taken two or three steps toward the truck when the detonator exploded. Fortunately the cap leads were being held 2 or 3 feet from the detonator, and although the shooter was painfully injured, he was not permanently disabled. It is believed that a static charge which had collected on the 60-foot lead wires ignited the detonator.

E. I. du Pont de Nemours & Company has built a static bridge in the form of a Y into the SSS detonator. It is reported that this detonator will eliminate the hazard of a detonation due to static electricity.

Of all hazards associated with explosives, those generally ascribed to static electricity are probably least understood. In 1942 the Explosives Control Division of the Bureau of Mines began an investigation of static electrical hazards associated with the manufacture, storage, and use of explosives. A considerable amount of data on static spark sensitivities of explosives has been accumulated, and some have been published in Bureau of Mines *Report of Investigations 3852* "Sensitivity of Explosives to Initiation by Electrostatic Discharges."

It is possible for static charges to accumulate on human beings or on ungrounded equipment or structures. Static charges may be produced in many ways, but they are most commonly produced by successive contact and separation of unlike surfaces, at least one of which is usually an insulator. A human being or a piece of equipment, such as a car or truck, acts as an electrical condenser, and, when any part of it comes close to another conductor, a spark can occur. Materials in the path of the discharge may be ignited if they are sensitive enough and the energy in the discharge is high enough. A number of tests were made to determine the minimum charge of static electricity to ignite different explosives materials; after the tests were completed the following conclusions were reached:

"1. The energy for ignition varies with voltage and overvoltage, but the trend of variation is not the same for all explosives . . . .

"2. Large particles ignite less readily than smaller particles, although for some explosives under confinement this effect is not appreciable.

"3. Except for primary explosives, the degree of confinement usually has a marked effect upon ease of ignition and completeness of propagation of the ignition.

"4. Ignitions of secondary high explosives unconfined are apparently explosions of fine dust dispersed into the air by the spark, whereas under confinement these explosives detonate.

"5. The ignition energies for unconfined samples of finely ground secondary high explosives were invariably less than for the same types of samples under confinement.

"6. Metal powders are more sensitive when tested unconfined.

"7. Black powder is much more sensitive when tested under confinement.

"8. Moist black powder (up to 7 percent moisture) is more sensitive than dry black powder when tested under partial confinement.

"9. Results to date indicate that less energy is required for ignition with a positive point, probably because corona losses are less."[7]

CONCLUSIONS

This brief review of the accidents that have occurred show that there is a need for establishing a set of standard safety regulations and that before any new equipment, such as aluminum loading poles, is introduced, the problem should be studied to insure that a new hazard is not introduced.

Only a safe geophysical crew operates economically and efficiently, and, in order to promote and maintain efficient operations, geophysical companies must not revert to the unsafe practices used prior to the war.

[7] F. W. Brown, D. J. Kusler, and F. C. Gibson, "Sensitivity of Explosives to Initiation by Electrostatic Discharges": *Bureau of Mines Report of Investigations 3852*, January 1946, pp. 4–7.

ANALYSIS OF TOTAL MAGNETIC-INTENSITY ANOMALIES PRODUCED BY POINT AND LINE SOURCES*

ROLAND G. HENDERSON† AND ISIDORE ZIETZ†

ABSTRACT

The component of total magnetic intensity in the direction of the earth's total field, the quantity measured by the airborne magnetometer, is studied in relation to point-pole and line-of-poles sources. Theoretical profiles are examined for maxima and minima, and it is established that the depth is a linear function of the half-maximum abscissa. A family of curves is presented by means of which factors can be obtained for use in estimating depths. The well-known factors used with vertical-intensity profiles are included as a special case. An example is given in which the factors are used in analyzing a theoretical anomaly.

In the interpretation of magnetic anomalies, it is often convenient to obtain depth estimates by assuming the source to be a point pole or a line of poles. Rules for quick estimation of depth from vertical-intensity profiles are well known. Similar rules applicable to total-intensity profiles, such as those resulting from aeromagnetic surveys, are developed here, and some of the problems peculiar to interpretation of total-intensity anomalies are discussed. An example is given in which a theoretical anomaly is analyzed.

For anomalies which are characterized by nearly circular contours, it may be assumed tentatively that the source is a point pole. Geologically it may be represented by a long, thin cylinder parallel to and polarized by induction in the earth's magnetic field. The length of the cylinder is assumed to be so great in relation to the depth that the effect of the lower pole on the plane of observations is negligible. Elongated anomalies may be regarded as having been produced by a line of poles. Its geological analogue could be an infinitesimally thin magnetized sheet of great horizontal dimension, parallel to and extending indefinitely in the direction of the earth's field.

The airborne magnetometer measures, except for a known additive quantity ΔT, the component of the total intensity anomaly in the direction of the total field. The direction of the vector ΔT, therefore, is a primary consideration. If an anomaly has an amplitude of approximately 500 gammas or less and an area of a few hundred square miles, the average direction of the earth's normal field may be adopted as the direction of ΔT. Under these conditions it can be shown that the error introduced will be negligible. This error has been discussed briefly by Hughes and Pondrom.[1] In the discussion given here the invariance of the direction of the earth's normal field will be assumed.

* Published by permission of the Director, U. S. Geological Survey. Manuscript received by the Editor February 14, 1948.

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[1] D. S. Hughes, and W. L. Pondrom, "Computation of Vertical Magnetic Anomalies from Total Magnetic Field Measurements," *Trans. Amer. Geophys. Union, 28* (1947), 193–197.

POINT POLE IN NORTH MAGNETIC LATITUDE

The general mathematical expression for the ΔT-anomaly produced by a point pole is easily obtained from the anomalous potential ΔV. A right-handed system of cartesian coordinates is adopted as shown in Figure 1 where XOY is the plane of

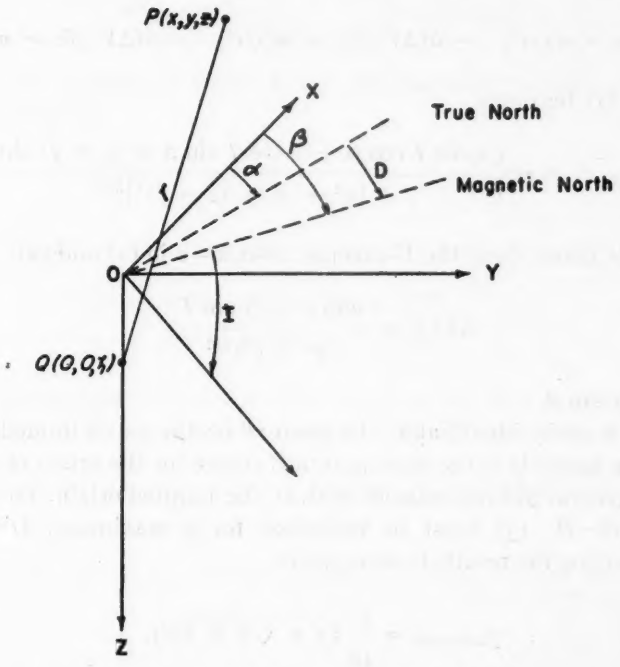

FIG. 1. Co-ordinate system with α=angle between x-axis and true north, β the angle between x-axis and magnetic north, D the declination, and I the inclination.

observations and is parallel to the earth's surface; the y-axis is positive in a northerly direction; and the z-axis is positive vertically downward. The angle between the positive x-axis and magnetic north is designated β and the inclination of the earth's field is designated I. Let $\mathbf{t}$ be the unit vector in the direction of the earth's normal (undisturbed) total field. Suppose a point source of strength m is located at $Q(0, 0, \zeta)$. At any point $P(x, y, z)$ the source will produce a potential

$$\Delta V = m/r \equiv \frac{m}{[x^2 + y^2 + (z - \zeta)^2]^{1/2}};$$

then

$$\Delta T = -\, d(\Delta V)/dt = -\left[\frac{\partial(\Delta V)}{\partial x}\,\frac{dx}{dt} + \frac{\partial(\Delta V)}{\partial y}\,\frac{dy}{dt} + \frac{\partial(\Delta V)}{\partial z}\,\frac{dz}{dt}\right]. \qquad (1)$$

Since

$$dx/dt = \cos(x, t) = \cos I \cos\beta; \qquad dy/dt = \cos(y, t) = \cos I \sin\beta;$$
$$dz/dt = \cos(z, t) = \sin I;$$

and

$$-\partial(\Delta V)/\partial x = mx/r^3, \quad -\partial(\Delta V)/\partial y = my/r^3, \quad -\partial(\Delta V)/\partial z = m(z-\zeta)/r^3;$$

then equation (1) becomes

$$\Delta T(x, y, z) = m\left\{\frac{x\cos I\cos\beta + y\cos I\sin\beta + (z-\zeta)\sin I}{[x^2+y^2+(z-\zeta)^2]^{3/2}}\right\}. \tag{2}$$

For a profile taken along the Y-axis put $z=0$, $x=0$ in (2) and get

$$\Delta T(y) = \frac{m(ay-\zeta)\sin I}{(y^2+\zeta^2)^{3/2}}, \tag{3}$$

where $a=\cot I \sin\beta$,

Because it is easily identifiable, the point O' on the y-axis immediately below the peak of the anomaly is the most practical choice for the origin of coordinates. This point in general will not coincide with O, the adopted origin. To compute the displacement $O-O'$, (3) must be examined for a maximum. Differentiating $\Delta T(y)$ and equating the results to zero yields

$$y_{\text{min/max}} = \frac{\zeta}{4a}(3 \pm \sqrt{9+8a^2}). \tag{4}$$

Since the y-axis is chosen positive in the north halfplane, then $0 \leqq \beta \leqq 180°$ and $\sin\beta$ is never negative. Therefore, $a \geqq 0$ in north magnetic latitudes. But for $a \geqq 0$ it can be shown that $y_{\max} \leqq 0$ and the abscissa of the maximum is given by the negative sign in equation (4). This means that in these latitudes the peak is never north of a point source; a result which agrees with a conclusion of I. Roman.[2]

The transformation equation is

$$y = y' + \gamma\zeta$$

where

$$\gamma = \frac{1}{4a}(3 - \sqrt{9+8a^2}),$$

and y' denotes distance from the new origin.

[2] I. Roman, "The Resolving Power of Magnetic Observations" *AIME Technical Publication No. 2097*, November, 1946.

Equation (3) becomes

$$\Delta T(y') = \frac{m[(y' + \gamma\zeta)a - \zeta] \sin I}{[(y' + \gamma\zeta)^2 + \zeta^2]^{3/2}}; \tag{5}$$

$$\Delta T_{\max} = \frac{m(a\gamma - 1) \sin I}{\zeta^2(\gamma^2 + 1)^{3/2}}. \tag{6}$$

Let η be the abscissa at which $\Delta T(y')$ has declined to $\frac{1}{2}\Delta T_{\max}$. Substituting this value in (5) gives

$$\tfrac{1}{2}\Delta T_{\max} = m\left\{\frac{(\eta + \gamma\zeta)a - \zeta}{[(\eta + \gamma\zeta)^2 + \zeta^2]^{3/2}}\right\} \sin I. \tag{7}$$

Solving (6) and (7) simultaneously we have

$$\frac{[(\eta + \gamma\zeta)a - \zeta]\zeta^2}{[(\eta + \gamma\zeta)^2 + \zeta^2]^{3/2}} \frac{(\gamma^2 + 1)^{3/2}}{(1 - a\gamma)} + \frac{1}{2} = 0. \tag{8}$$

Regarding equation (8) as an implicit function, say $\phi(\eta, \zeta)$, we establish that ζ is a linear function of η and derive a very useful depth rule.

$$\frac{\partial\phi}{\partial\zeta} = \zeta\eta\left\{\frac{\zeta^2[3\gamma(a\gamma-1)-a-a\gamma^2]+\zeta\eta[3(a\gamma-1)+a\gamma]+2a\eta^2}{[(\gamma\zeta+\eta)^2+\zeta^2]^{5/2}}\right\}\frac{(\gamma^2+1)^{3/2}}{(1-a\gamma)}$$

$$\frac{\partial\phi}{\partial\eta} = -\zeta^2\left\{\frac{\zeta^2[3\gamma(a\gamma-1)-a-a\gamma^2]+\zeta\eta[3(a\gamma-1)+a\gamma]+2a\eta^2}{[(\gamma\zeta+\eta)^2+\zeta^2]^{5/2}}\right\}\frac{(\gamma^2+1)^{3/2}}{1-a\gamma}$$

$$\frac{d\eta}{d\zeta} = -\frac{\dfrac{\partial\phi}{\partial\zeta}}{\dfrac{\partial\phi}{\partial\eta}} = \frac{\eta}{\zeta}, \quad \text{and} \quad \zeta = k_1(a)\eta, \tag{9}$$

where k_1 is the constant of integration and dependent upon a. A sixth degree equation in ζ is obtained by substituting in equation (8) a particular value of a and any convenient $\eta > 0$. Although there are six possible solutions for ζ, the calculations yield only one positive real root within the desired range. The numerical solution was obtained by the method of false position and the required k_1 was then determined from equation (9).

For convenient presentation a family of curves was plotted (see Fig. 2) from the relation $\cot I \sin \beta = a$, for the various values a for which k_1 had been determined. The values a do not appear explicitly in the graph.

As an illustration of the manner in which the factors k_1 are used, a theoretical total-intensity anomaly produced by a thin vertical prism extending indefinitely downward is presented in Figure 3. The cross section is a square the side of which is

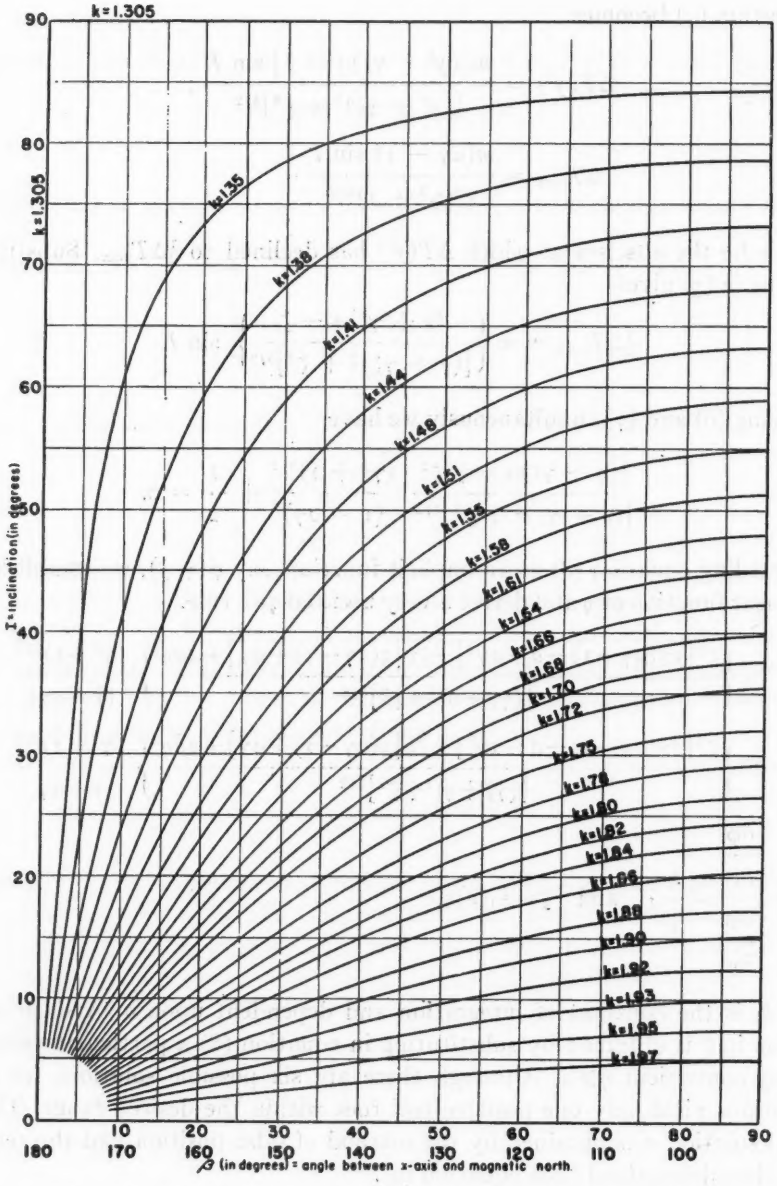

FIG. 2. Total-intensity half-maximum factors for depth to point source.

one-half the depth of burial. The body is assumed to be polarized by induction in the earth's magnetic field, inclination 75°. For practical purposes this anomaly may be regarded as approximating that of a point pole. Note that the maximum is shifted slightly south of the center of the body. The minimum, which is not

shown in the figure, is known to approximate the zero contour towards the north.

To get an estimate of depth, suppose we consider a profile with a magnetic bearing of N 30° E. Taking the origin at the maximum and the y-axis positive to

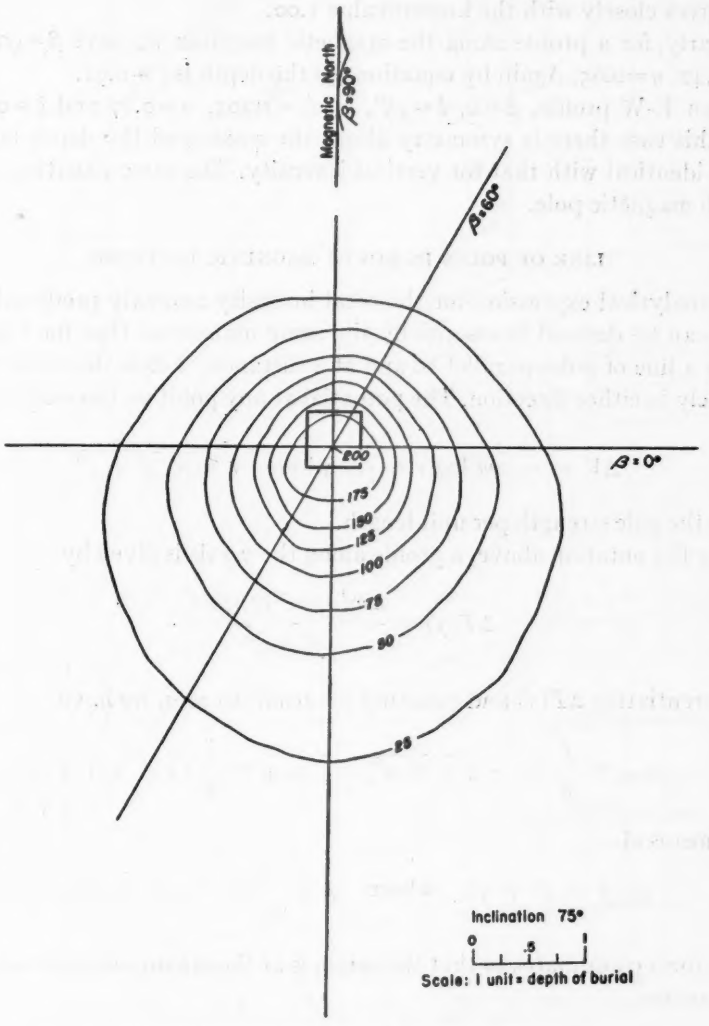

FIG. 3. Theoretical total-intensity anomaly over long vertical prism.

the north, β is then 60°. With $I=75°$ and $\beta=60°$ as arguments, interpolate in Figure 2 obtaining $k_1=1.39$.

The difference between the maximum and minimum values of the anomaly, which is designated ΔT_{max} is 200 units. The point η at which ΔT has dropped to

$\Delta T_{max}/2$ is scaled as 0.7 the depth interval. Substituting these values of k_1 and, η in equation (9), we have

$$\zeta = 1.39 \times 0.70 = 0.97,$$

which agrees closely with the known value 1.00.

Similarly, for a profile along the magnetic meridian we have $\beta = 90°$, $I = 75°$, $k_1(a) = 1.40$, $\eta = 0.65$. Again by equation (9) the depth is $\zeta = 0.91$.

For an E-W profile, $\beta = 0$, $I = 75°$, $k_1(a) = 1.305$, $\eta = 0.87$ and $\zeta = 0.99$. Note that in this case there is symmetry about the z-axis and the depth factor $k_1(a)$ becomes identical with that for vertical intensity. The same situation obtains at the north magnetic pole.

LINE OF POLES IN NORTH MAGNETIC LATITUDE

The analytical expression for the total intensity anomaly produced by a line of poles can be derived in essentially the same manner as that for a point pole. Consider a line of poles parallel to and at a distance ζ below the x-axis extending indefinitely in either direction. The potential at any point on the y-axis is given by

$$\Delta V = -2m \log r + c, \quad \text{where} \quad r = \sqrt{y^2 + \zeta^2},$$

and m is the pole strength per unit length.

Using the notation above, a profile along the y-axis is given by

$$\Delta T(y) = \frac{2m(ay - \zeta) \sin I}{y^2 + \zeta^2}. \tag{10}$$

Differentiating $\Delta T(y)$ and equating the result to zero, we have

$$y_{max} = \frac{\zeta}{a}(1 - \sqrt{1 + a^2}), \qquad y_{min} = \frac{\zeta}{a}(1 + \sqrt{1 + a^2}).$$

By means of

$$y = y' + \gamma\zeta, \quad \text{where} \quad \gamma = \frac{1}{a}(1 - \sqrt{1 + a^2}),$$

we transform coordinates so that the origin is at the maximum point and equation (10) becomes

$$\Delta T(y') = \frac{2m[a(y' + \gamma\zeta) - \zeta] \sin I}{(y' + \gamma\zeta)^2 + \zeta^2}.$$

Consequently,

$$\Delta T_{max} = \frac{2m(a\gamma - 1) \sin I}{(\gamma^2 + 1)\zeta}. \tag{11}$$

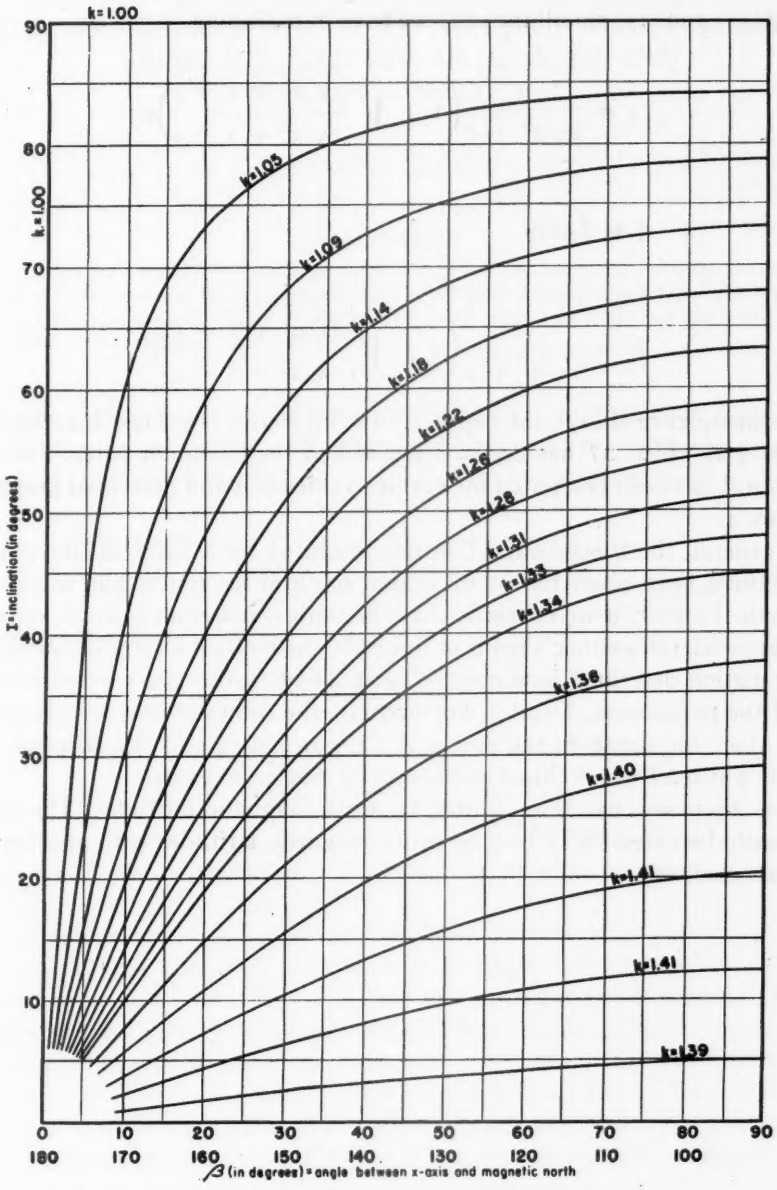

FIG. 4. Total-intensity half-maximum factors for depth to line source.

Calling η the abscissa at which $\Delta T(y')$ has declined to $\Delta T_{max}/2$

$$\Delta T_{max/2} = \frac{2m[a(\eta + \gamma\zeta) - \zeta] \sin I}{(\eta + \gamma\zeta)^2 + \zeta^2}. \qquad (12)$$

Solving (11) and (12) simultaneously we have immediately

$$\zeta = \frac{a}{2\sqrt{a^2+1}}\left(1+\sqrt{\frac{3\sqrt{a^2+1}-1}{\sqrt{a^2+1}-1}}\right)\eta, \tag{13}$$

or

$$\zeta = k_2(a)\eta,$$

where

$$k_2 = \frac{a}{2\sqrt{a^2+1}}\left(1+\sqrt{\frac{3\sqrt{a^2+1}-1}{\sqrt{a^2+1}-1}}\right).$$

In consequence of (13), the depth, ζ, to a line source is a linear function of the abscissa η at which ΔT has declined to one-half its maximum value. The depth factor $k_2(a)$ has been computed for various values of a and presented graphically in Figure 4.

In general, the theoretical ΔT-profile produced by a point or line source in the northern hemisphere has its maximum south of the source and minimum to the north. Further, if we conclude that the source, based on geologic considerations, approximates either a point or line pole, the method for approximate depth determination described here may be used. The k-factors are plotted as a function of the parameters, I and β. Fortunately, the computations are greatly simplified since the depth to the source is a linear function of the abscissa, η, the point at which ΔT has declined to one-half its maximum value.

This discussion has been limited to north magnetic latitudes. The analysis may easily be extended to include south magnetic latitudes with another set of k-factors resulting.

THE DETERMINATION OF AN INFINITE INCLINED DIKE FROM THE RESULTS OF GRAVITY AND MAGNETIC SURVEYS*

LASZLO EGYED†

ABSTRACT

The equations are given for the gravitational gradient and curvature, and for the horizontal and vertical components of the magnetic anomaly for ore bodies of the Kursk type. It is then shown how from these equations the depth, width of crest, angle of dip, anomalous density and magnetic susceptibility of the body may be determined.

The subsurface masses causing the classic magnetic anomalies at Kursk and at Kiirunavaara have, besides their great magnetic effects, considerable gravity effects also. In order to determine the data of such subsurface masses, it is prac-

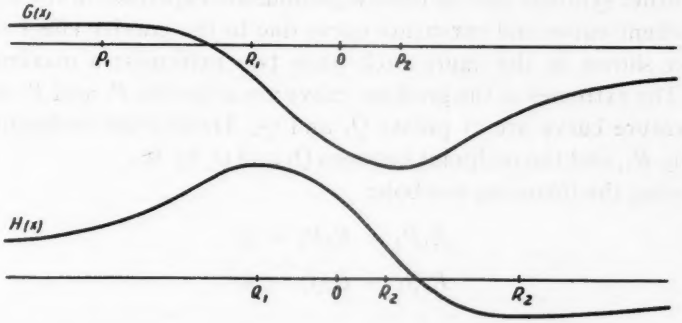

FIG. 1. Curves of gravitational gradient and curvature across an inclined dike.

tical to consider not only their magnetic effects but also their gravity effects. In the following, two analogous methods will be given to determine the data of a subsurface dike: first, from the gravity survey; second, from the magnetic survey.

The cross-section of a subsurface inclined block (dike) is shown on Figure 1. It is supposed that downwards, and normally to the plane of Figure 1, the block extends to the infinite, i.e., that it is an infinite inclined block. The gravity and magnetic effects of such an infinite inclined block are practically the same as those for a block of large, though finite, length and depth. The magnetic anomalies at Kursk and Kiirunavaara are caused by such masses.

The gravity anomalies of the mass shown in Figure 1, at the surface at point P (with abscissa x) are given by the following equations:

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The gradient:

$$G(x) = -2f\Delta\sigma \sin\alpha\left[\sin\alpha \ln\frac{R}{r} - \cos\alpha(\Phi - \phi)\right]$$

$$= -2f\Delta\sigma \sin\alpha\left[\sin\alpha \ln\frac{\sqrt{(x+d)^2+c^2}}{\sqrt{(x-d)^2+c^2}}\right.$$

$$\left. - \cos\alpha\left(\tan^{-1}\frac{c}{x+d} - \tan^{-1}\frac{c}{x-d}\right)\right]. \tag{1}$$

The curvature:

$$H(x) = -2f\Delta\sigma \sin\alpha\left[\cos\alpha \ln\frac{R}{r} + \sin\alpha(\Phi - \phi)\right], \tag{2}$$

where $\Delta\sigma$ is the relative density, f is the gravitational constant 66.7×10^{-9} c.g.s. units. The other symbols used in these equations are explained in the figure.

The gradient curve and curvature curve due to the gravity effect of the subsurface dike shown in the figure each have two extremes: a maximum and a minimum. The extremes of the gradient curve are at points P_1 and P_2 while those of the curvature curve are at points Q_1 and Q_2. Denote the midpoint between P_1 and P_2 by R_1, and the midpoint between Q_1 and Q_2 by R_2.

Introducing the following symbols:

$$R_1P_1 = R_1P_2 = g, \tag{3}$$

$$R_2Q_1 = R_2Q_2 = h, \tag{4}$$

and

$$R_1R_2 = l, \tag{5}$$

The dip of the dike is determined by the following equation:*

$$\frac{g^2 - h^2}{l^2} = \cos 2\alpha. \tag{6}$$

In order to verify this statement, the coordinates of the extremes of the gradient and curvature curves should be determined. The extremities are at those places

* If the curve is rather flat, in that case the location of the extremes may be uncertain. Then it is practical to use the approximation expressed by the Nikiforov-Jung formula:

$$\frac{G_{max}+G_{min}}{H_{max}+H_{min}} = \cot\alpha$$

where G_{max} and G_{min} are the maximum and minimum values of the gradient curve, and H_{max} and H_{min} those of the curvature curve. Using this formula when the curves are steep would introduce a considerable error in those cases, but in these cases the extremes can be easily located by inspecting the curves, and without using any formulas.

where the first derivatives of the functions of the gradient and curvature curves (equations (1) and (2)) are zero.

$$G'(x) = -2f\Delta\sigma \sin\alpha\left\{\sin\alpha\left[\frac{x+d}{(x+d)^2+c^2} - \frac{x-d}{(x-d)^2+c^2}\right] + \cos\alpha\left[\frac{c}{(x+d)^2+c^2} - \frac{c}{(x-d)^2+c^2}\right]\right\} = 0.$$

$$H'(x) = -2f\Delta\sigma \sin\alpha\left\{\cos\alpha\left[\frac{x+d}{(x+d)^2+c^2} - \frac{x-d}{(x-d)^2+c^2}\right] - \sin\alpha\left[\frac{c}{(x+d)^2+c^2} - \frac{c}{(x-d)^2+c^2}\right]\right\} = 0.$$

Arranging these equations according to the powers of x, and ζ the extremes at the x- and ζ-values are determined by the following equations:

For the gradient curve:

$$x^2 + (2c\cot\alpha)\cdot x - (c^2+d^2) = 0,$$

and for the curvature curve:

$$\zeta^2 - 2c\tan\alpha\cdot\zeta - (c^2+d^2) = 0.$$

From the first equation:

$$x_1 = -c\cot\alpha + \sqrt{c^2\cot^2\alpha + (c^2+d^2)},$$

$$x_2 = -c\cot\alpha - \sqrt{c^2\cot^2\alpha + (c^2+d^2)}.$$

$$g^2 = \left(\frac{x_1 - x_2}{2}\right)^2 = c^2\cot^2\alpha + (c^2+d^2) = \frac{c^2}{\sin^2\alpha} + d^2.$$

From the second equation:

$$\zeta_1 = +c\cdot\tan\alpha + \sqrt{c^2\cdot\tan^2\alpha + (c^2+d^2)}$$

$$\zeta_2 = +c\cdot\tan\alpha - \sqrt{c^2\cdot\tan^2\alpha + (c^2+d^2)},$$

from which

$$h^2 = \left(\frac{\zeta_1 - \zeta_2}{2}\right)^2 = c^2\tan^2\alpha + (c^2+d^2) = \frac{c^2}{\cos^2\alpha} + d^2.$$

Finally from both equations

$$l = \frac{\zeta_1+\zeta_2}{2} - \frac{x_1+x_2}{2} = c(\cot\alpha + \tan\alpha) = \frac{2c}{\sin 2\alpha}.$$

From the three equations (giving the values g^2, h^2 and l)

$$g^2 - h^2 = c^2(\cot^2 \alpha - \tan^2 \alpha) = \frac{4c^2 \cos 2\alpha}{\sin^2 2\alpha} = l^2 \cos 2\alpha,$$

which furnishes the proof of the equation (6): $(g^2-h^2)/l^2=\cos 2\alpha$ given above. The depth to the top of the dike may be determined also from the equation

$$l = 2c/\sin 2\alpha,$$

namely:

$$c = \frac{l}{2} \sin 2\alpha = \frac{l}{2}\sqrt{1 - \left(\frac{g^2 - h^2}{l^2}\right)^2}. \tag{7}$$

The width of the dike is given by equation

$$2d = 2\sqrt{\frac{g^2 + h^2 - l^2}{2}}, \tag{8}$$

which can easily be proven.

The center of the top of the dike may be found by measuring (considering the sign also) the distance $+c \cot \alpha$ from point R_1, or, the distance $-c \tan \alpha$ from point R_2.

These formulas, except the one determining the dip, are valid only when

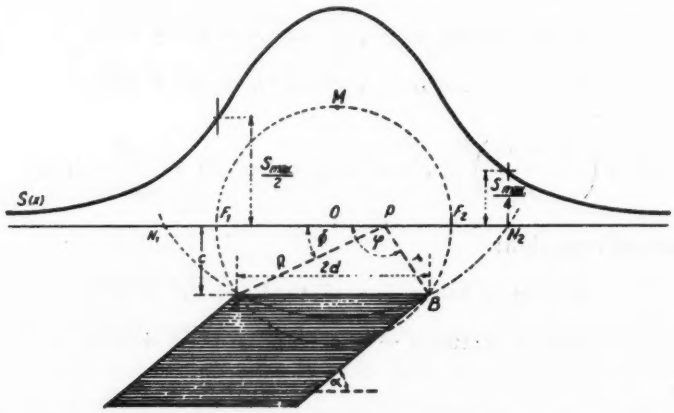

FIG. 2. Determination of the width and depth of the top of the dike by means of the function $S(x)$.

$\alpha \neq (\pi/2)$. For this reason a method free of this restriction is also given below.

Knowing already the value of α, consider the following function:

$$S(x) = H(x) - G(x) \cot \alpha = -2f \cdot \Delta\sigma(\Phi - \phi). \tag{9}$$

The curve $S(x)$ (Fig. 2) defined by equation (9) is symmetrical, and its maximum occurs over the center of the dike. Let F_1 and F_2 be points where the value

of curve $S(x)$ is half of the maximum value, and also let N_1 and N_2 be those where the values of the curve are equal to one-fourth of the maximum value.

Draw a circle with F_1F_2 as diameter, and erect a line at the center of this circle perpendicular to the surface. This perpendicular line will intersect the circle at point M. Using point M as center, draw another circle with radius $MN_1 = MN_2$. The common chord of these two circles determines the top (i.e. the depth and width) of the subsurface dike. As α is already known, the dike is completely determined.

The correctness of this graphical method can readily be seen by considering that $S(x)$ is solely a function of the angle $(\Phi-\phi)$, and that the angle drawn on a chord from the center point of the circle is twice as large as the angle drawn on the same chord from a peripheral point of the circle.

The maximum value of $(\Phi-\phi)$ can be measured as soon as the inclined block is defined by the graphical method described above. Substituting the maximum value of $(\Phi-\phi)$ and of $S(x)$ into equation (9) the relative density $\Delta\sigma$ may be determined:

$$\Delta\sigma = \frac{S_{\max}}{-2f(\Phi-\phi)_{\max}}. \tag{10}$$

The magnetic anomalies of the same infinite inclined block are:

$$\Delta H = -2\kappa \sin\alpha\left[(Z_0 \sin\alpha - H_0 \sin\epsilon\cos\alpha)\ln R/r - (Z_0\cos\alpha + H_0\sin\epsilon\sin\alpha)(\Phi-\phi)\right]; \tag{11}$$

$$\Delta Z = -2\kappa \sin\alpha\left[(Z_0\cos\alpha + H_0\sin\epsilon\sin\alpha)\ln R/r + (Z_0\sin\alpha - H_0\sin\epsilon\cos\alpha)(\Phi-\phi)\right], \tag{12}$$

where ΔH is the anomaly of the horizontal component, ΔZ is the anomaly of the vertical component of the earth magnetic field, ϵ is the angle between the strike and the magnetic meridian, κ is the magnetic susceptibility of the masses causing the anomaly, and finally H_o and Z_o are the local values of the horizontal and vertical componenets of the earth magnetic field, respectively. Factoring out $\sqrt{Z_o^2+H_o^2\sin^2\epsilon}$ from the equation and introducing ψ defined by equation:

$$\cot\psi = \frac{Z_0}{H_0\sin\epsilon} = \frac{\tan i}{\sin\epsilon};$$

then equations (11) and (12) can be written as follows:

$$\Delta H = -2\kappa\sin\epsilon\sqrt{Z_0^2+H_0^2\sin^2\epsilon}\,[\sin(\alpha-\psi)\ln(R/r) - \cos(\alpha-\psi)(\Phi-\phi)]; \tag{13}$$

$$\Delta Z = -2\kappa\sin\epsilon\sqrt{Z_0^2+H_0^2\sin^2\epsilon}\,[\cos(\alpha-\psi)\ln(R/r) + \sin(\alpha-\psi)(\Phi-\phi)]. \tag{14}$$

These equations clearly show the analogy between the values ΔH and ΔZ and the values $G(x)$ and $H(x)$, respectively.* Analogously, as in the method given to

* The author wishes to acknowledge here that Dr. Raoul Vajk called his attention to the possibility of this analogy.

interpret the gravity anomalies, denote by P_1 and P_2 the points where the ΔZ-curve has its extremes, and by Q_1 and Q_2 the points where the ΔH-curve has its extremes, finally let R_1 be the midpoint of the length P_1P_2 and R_2 that of Q_1Q_2, then the distances g, h and l will similarly determine the angle α:

$$\frac{g^2 - h^2}{l^2} = \cos 2(\alpha - \psi). \tag{15}$$

As the value of ψ is given by the equation

$$\psi = \cot^{-1}(tgi/\sin \epsilon),$$

α can also be determined purely from the magnetic data.

Eliminating $\ln(R/r)$ from equations (13) and (14) the following equations are obtained.

$$\begin{aligned} \Delta S &= + \Delta Z - \Delta H \cdot \cot(\alpha - \psi) \\ &= - 2\kappa \sqrt{Z_0^2 + H_0^2 \sin^2 \epsilon} \cdot \frac{\sin \alpha}{\sin(\alpha - \psi)} (\Phi - \phi); \end{aligned} \tag{16}$$

that is,

$$\Delta S = - 2\kappa \cdot C(\Phi - \phi). \tag{17}$$

As α is already known from equation (15) and the values of ΔZ and ΔH are given, ΔS can be determined from the observed values for every point, and its values are functions of the angle $(\Phi - \phi)$ only. The same graphical method can be applied on this ΔS-curve as was applied above when the gravity data were used. The susceptibility κ of the masses causing the magnetic anomaly can be determined in an analogous manner to that by which the relative density was determined from the gravity anomalies.

IS IT AN ANOMALY?*

R. MAURICE TRIPP†

ABSTRACT

A method is proposed and described whereby it is possible to examine statistically the data from a geophysical survey to determine the relative probability of its occurring as a result of pure chance. When the probability is less than 0.01, a technique is outlined for further "reducing" the data in an objective manner and testing anomalous areas for significance. The method is particularly applicable to highly variable data which result from random background fluctuations found in some of the modern prospecting techniques.

THE PROBLEM

The interpreter of certain types of geophysical data is often confronted with the problem of deciding whether variations in the data presented him are meaningful in terms of commercially important anomalies. Present-day refinements in many of the geophysical techniques have pushed the observation range to the noise-level limit of the equipment and/or field being investigated. Statistical fluctuation in the measured quantity plus the random error of reading the instrument at high magnification combine to produce a variable background above which it is desired to detect significant variations. These unassignable variations are to be expected and are inherent in all precisely taken data. They can not be eliminated by taking multiple observations at each point. If a second or third or n number of surveys were run, each would probably deviate from all previous ones by a small but finite amount. Any single observation at a given station provides us with an estimate of the true value at that station and, further, this estimate has a determinable probability of not deviating from the true value by more than an assignable amount. Multiple observations at a point merely improve the estimate of the true but unknown value and narrow the limits of probable deviation from the true value.

There is usually little doubt in the geophysicist's mind regarding the presence of gross anomalies; however a series of observations which differ only slightly from the normal may also be significant if they can be shown to have a high probability of being due to factors other than chance. This is a problem in statistical evaluation. We can not remove the effect of chance on the data but we can measure its effect and thereby reduce the doubt in making subsequent decisions.

GENERAL PLAN OF SOLUTION

To examine a set of data statistically, we first set up a hypothesis regarding the data and then proceed to determine the probability of its being correct. For

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instance our hypothesis might be: there is no anomaly present. We then proceed to evaluate the probability that all observations were really made over a single-valued field.* If no anomalies exist in the area being surveyed, a plot of the station values as abscissa and frequency of occurrence as ordinate will have the appearance of a normal-distribution curve peaking at the mean (see Fig. 1).

The deviation of the values about the mean may be described numerically by the standard deviation†, σ, defined by

$$\sigma = [\sum (x - \overline{X})^2/(n - 1)]^{1/2},$$

where x is the value at any station, $\overline{X}$ the mean value of all stations, and n the total number of stations.

The significance of the standard deviation and its relation to the frequency-

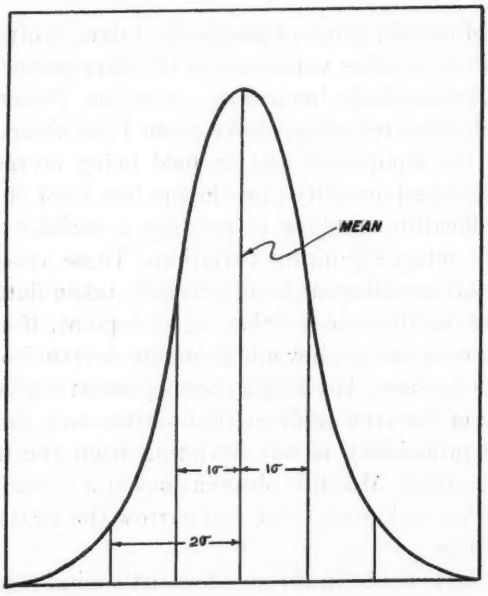

FIG. 1. Normal-distribution curve according to the Gaussian law.

distribution curve is better understood if we note that the area under the curve between $\overline{X} \pm \sigma$ includes over 68 percent of the total area. Likewise, more than 95 percent of the values will be included between $\overline{X} \pm 2\sigma$ and 99.7 percent will fall within $\overline{X} \pm 3\sigma$. To look at it another way, when making measurements over a uniform field, the probability of obtaining a station value deviating from the mean by more than 3σ is 0.0027.

* It is essential to the theory and the subsequent computations that any "regional" influence shall have been removed from the data.

† Standard deviation may be expressed in a simpler form for ease in computation as: $\sigma = \Sigma x^2 - [(\Sigma x)^2/n]$ when n is greater than 30.

If the field being investigated is not uniform, the station values will not fall along the normal curve of frequency distribution but will be distorted or skewed in the direction of the anomalous values. This characteristic provides us with a means for recognizing irregularities in the data which can not be accounted for on the basis of chance.

To take advantage of this property, we compute one or more constants describing the frequency distribution of the data. Then determine the probability

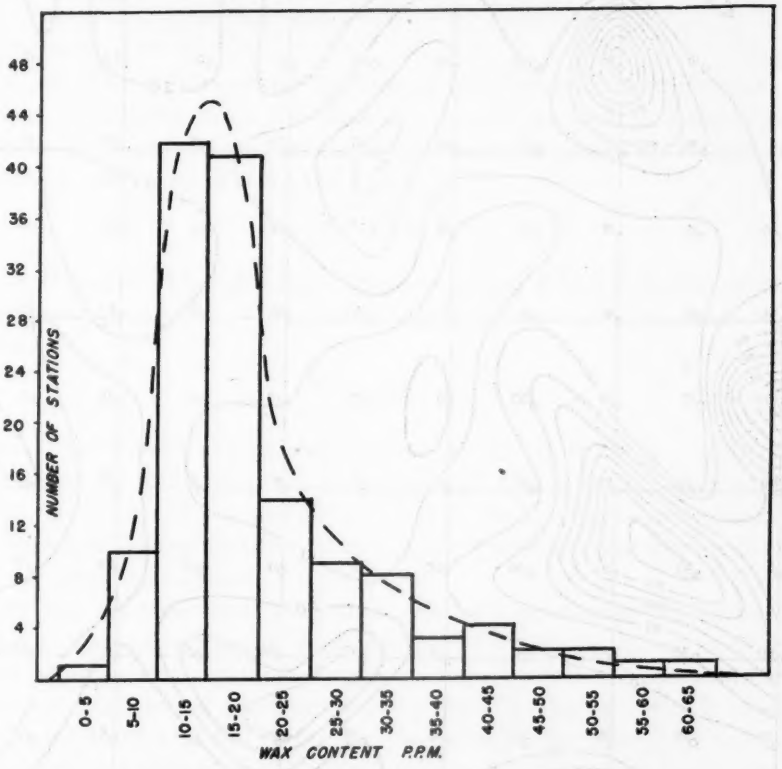

FIG. 2. Histogram of soil-wax data from survey in northern Oklahoma.

that the computed constants could have been derived from "normal" data. We agree that if the probability turns out to be less than 0.01 that the data are most likely not normal but contain anomalies. We then plot the station values on a map, after suitable reduction, and contour them. The anomalous areas may be tested for significance by assuming them to be a collection of random errors and computing the probability that such a condition could occur. We can arbitrarily set the limiting probability small enough so we are satisfied the assumption is extremely unlikely when the limits are exceeded and therefore the anomaly must truly be significant and would always persist above the background variation.

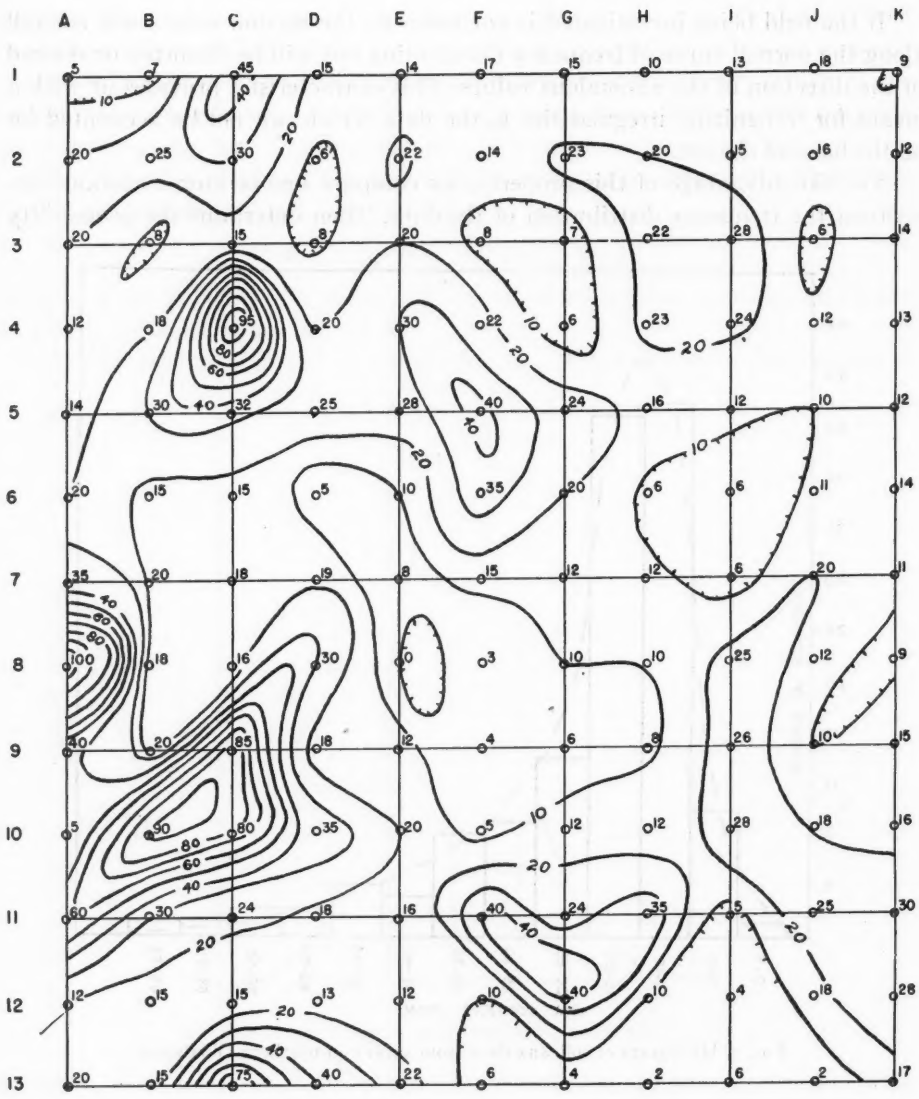

FIG. 3. Unreduced data of soil-wax concentration. Geochemical survey from northern Oklahoma. Contour interval = 10 ppm.

REDUCTION OF DATA

Running average.—There are many variables about which we can not obtain quantitative information; therefore it is proposed to minimize their effect in producing extreme variations between adjacent stations by determining a weighted average for each station value. A glance at the pattern of station layout, Figure

3, shows that each point has four closest and equidistant neighbors which occupy the corners of a diamond with the fifth point at the center. The mean of the four corners plus the center taken twice is assigned to the center station. Subsequent operations are performed on the smoothed data.

Determination of "normality."—To establish whether the data could be derived from a normal frequency distribution, we compute the value of $(b_1)^{1/2}$ which is a measure of the skewness. For perfectly normal data,

$$(b_1)^{1/2} = [\sum (x - \overline{X})^3/n]/[\sum (x - \overline{X})^2/n]^{3/2}$$

will equal zero.

The practical requirements of computation dictate a simplification which introduces a negligible error. Tabulate the data in the form of a frequency-distribution table. Assign all stations falling within a given group the midpoint value of the group. The mean, $\overline{X}$, then becomes:

$$\overline{X} = \sum (M.P. \times F)/n,$$

where $M.P.$ is the midpoint value of the group, and F is the number of stations occurring in the group.
Likewise:

$$(x - \overline{X}) = (M.P. - \overline{X})F.$$

Enter Table 1[1] with the number of total stations in the survey and compare the listed value of $(b_1)^{1/2}$ with that just computed. If it is larger than the figure in the table, the probability is less than 0.01 that the hypothesis of normality was right. Therefore we feel justified in concluding the data came from a collection containing anomalous values.

If the $(b_1)^{1/2}$ is sufficiently near zero to have a reasonable probability of its deviation being due to chance, we can not get very excited about a significant anomaly being present and further statistical treatment is unwarranted. Assume we decide in the favor of an anomaly being present. The next step is to get the best estimate possible of the normal field upon which the significant variation is superimposed and then examine statistically the deviation of station values from that normal.

Determination of most probable value of normal field.—Return to the tabulated frequency distribution. It is noted that there is a crowding of values about a central location with a tapering off toward higher and lower regions. These higher and lower regions contain the statistically unlikely observation. We wish to determine the most probable value of the field free from these abnormalities. This can be done by finding the mean, $\overline{X}_1$, of the stations grouped about the central tendency. Subtract an arbitrary constant value of F from all groups and

[1] Taken from the more extensive table of H. A. Freeman, *Industrial Statistics*, New York: John Wiley & Sons, 1944, p. 164.

neglect the groups which turn up with a negative value of frequency occurrence. The selection of F is a matter of personal judgment in which the object should be to make a selection which will eliminate all but the stable, central-tendency values. Compute the mean and standard deviation using only the new reduced frequency distribution.

This new mean, $\overline{X}_1$, gives us an estimate of the most likely value of the field if it were really single valued.

Deviation from the normal.—It is convenient to subtract the mean just obtained from the weighted average value at each station. The residual with its

TABLE 1. VALUE OF $(b_1)^{1/2}$ FOR LIMITING PROBABILITY OF 0.01

Size of Sample n	Probability Is Less than 0.01. Data are normal if $(b_1)^{1/2}$ exceeds this.	Size of Sample n	Probability Is Less than 0.01. Data are normal if $(b_1)^{1/2}$ exceeds this.
25	1:061	500	0.255
30	0.982	600	0.233
35	0.921	700	0.215
40	0.869	800	0.202
45	0.825	900	0.190
50	0.787	1000	0.180
60	0.723	1200	0.165
70	0.673	1400	0.152
80	0.631	1600	0.142
90	0.596	1800	0.134
100	0.567	2000	0.127
125	0.508	2500	0.114
150	0.464	3000	0.104
175	0.430	3500	0.096
200	0.403	4000	0.090
250	0.360	4500	0.085
300	0.329	5000	0.081
350	0.305		
400	0.285		
450	0.269		

appropriate sign indicates the departure of the field at that point from the normal. A more expressive method of representing the deviation about the mean is to form the ratio of the residual with the standard deviation. This delineates the anomalous area well because the zero contour represents the most probable value for the anomaly-free field and about two-thirds of the normal values lie between $+1\sigma$ and -1σ contours.

Elkins[2] has proposed a test for anomaly significance which assumes that an anomaly is a collection of random errors; the probability of this being true is calculated, and the anomaly is accepted or rejected according to whether the

[2] T. A. Elkins, "The Reliability of Geophysical Anomalies on the Basis of Probability Considerations," *Geophysics*, V (1940), p. 321.

calculated probability is less or greater than some limiting value. The calculation is reduced to reference to a table which is reproduced in part as Table 2.

In using the table it is assumed that: (1) all errors are independent, and (2) the errors follow a Gaussian error function.

Use of the method consists of counting the number of stations within a contour of m standard deviations, and by reference to the table, verifying that the number of counted stations equals or exceeds the number required for significance at the particular level $m\sigma$.

Elkins has selected 4σ (about 0.00006) as the limiting probability. Another way of stating it is that there is a probability of 0.00006 or less that the stations within the selected contour could have occurred thus as a result of chance. This is a rather stringent requirement; therefore only high-ranking, significant anomalies can pass the test.

TABLE 2. RELATION BETWEEN ANOMALY AMPLITUDE AND NUMBER OF SUPPORTING STATIONS IF PROBABILITY LIMIT IS SET AT 4σ

Anomaly Amplitude $m\sigma$	Minimum Number of Stations Required if Probability for Chance Occurrence Is 0.00006
0.1^{σ}	14
0.2	12
0.3	11
0.4	10
0.5	9
0.6	8
0.8	7
1.0	6
1.5	4
2.0	3
3.0	2
4.0	1

APPLICATION OF THE METHOD

Data from a geochemical survey in northern Oklahoma are reduced by the method just described to better illustrate its application and usefulness.

Figure 3 is a map of the original sample data contoured in the conventional manner. Let Q designate the quantity contoured. The running average value of this quantity for each station is computed in the following manner illustrated by station B-2:

$$\overline{Q}_{B\text{-}2} = (Q_{B\text{-}1} + Q_{C\text{-}2} + Q_{B\text{-}3} + Q_{A\text{-}2} + 2Q_{B\text{-}2})/6 = 19.$$

The station values so obtained are grouped as a frequency distribution (Fig. 2). The mean, $\overline{X}$, is determined as 20.4 and the $(b_1)^{1/2}$ is 2.16. From Table 1 we find for 150 stations, $(b_1)^{1/2}$ must exceed 0.464 if there is a likelihood of 0.01 or less that it was computed from normal data. We conclude the data are abnormal and proceed to evaluate the anomalies.

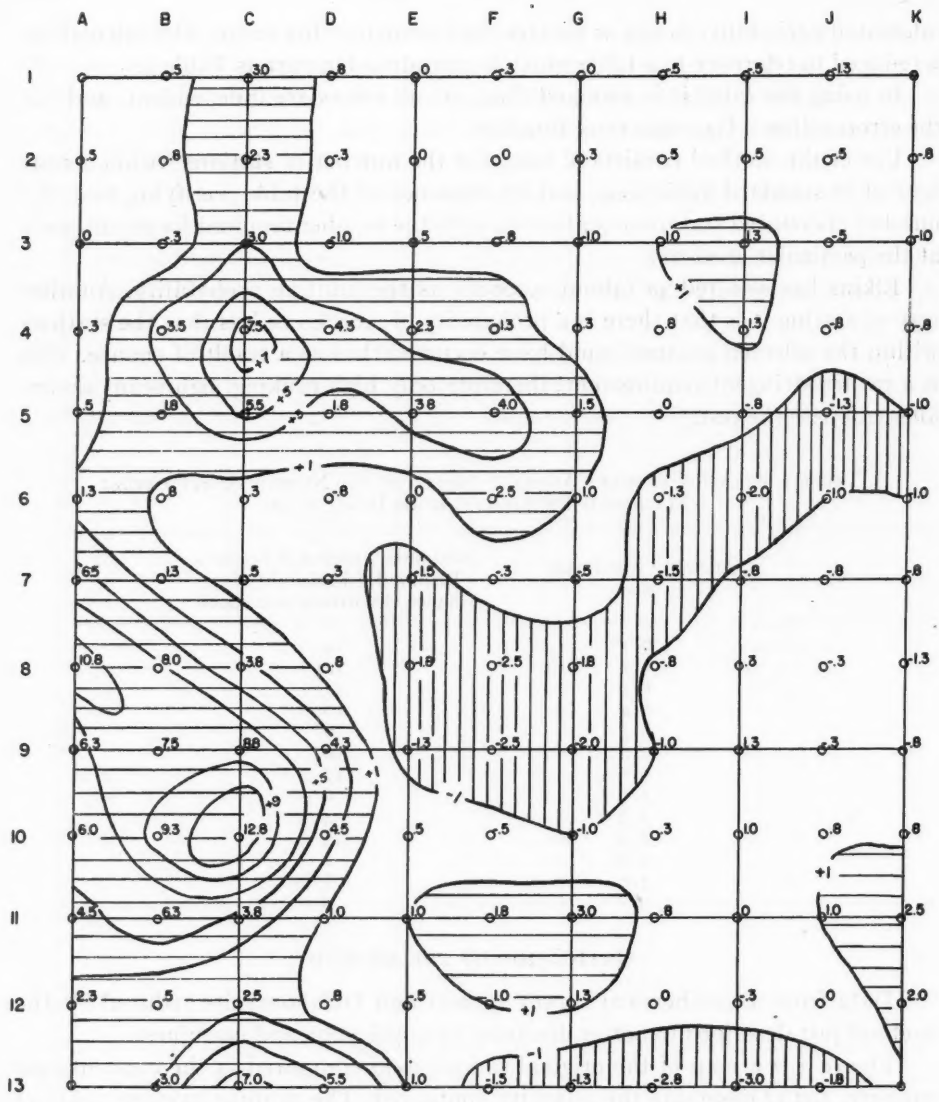

FIG. 4. Anomaly map from data of Figure 3 after reduction and testing for significance. Contour interval=2σ.

We decide after reference to Figure 2, that by subtracting $F=8$ from each group and considering a new set of data composed only of the groups with a positive remainder, that we will have a maximum of the normal stations and a minimum of the abnormal ones. The mean, $\overline{X}_1$, and standard deviation, σ_1, are computed for these new data and the stations are assigned new values obtained by : New value=(5 point average$-\overline{X}_1)/\sigma_1$.

The resulting anomaly map is contoured with reference to Elkins' test for significance and any contour which fails to qualify is omitted. Figure 4 is the resulting anomaly map from the data of Figure 1.

RÉSUMÉ

Statistical methods do not have the ability to tell us which is the correct answer, given several alternative interpretations; however, they do provide a method of evaluating the relative probability with which a given set of data might occur in nature due to pure chance. The more improbable such a condition becomes, the more likely is the possibility that the data describe a "real" anomaly. On the other hand when the amplitude of the suspected anomaly becomes so small as not to exceed the random variation in the background, it is not possible to establish its presence with a reasonably high probability of correctness and the observational limit of the technique has been reached.

Although a statistical examination of geophysical data should permit the interpreter to assign appropriate significance to anomalies encountered, it should in no way be construed that such a procedure will improve the accuracy of the data if the accuracy is not inherent in the original measurements.

The method described here is rough and somewhat crude in many respects, but these simplications seem justified when considering the practical aspects of computation required to reduce the data of a large survey.

OCEAN BOTTOM SAMPLER FOR SHIPS UNDER WAY*

J. L. WORZEL†

ABSTRACT

A simple bottom sampler has been developed which may be used from ships under way at speeds up to 12 knots. The sampler is allowed to fall freely under its own weight, and is recovered by reeling in a wire attached to the front. An open tube at the front will obtain about ½ pint of surface material from mud, sand, gravel, or coral bottoms. Existing models have been used in depths to 300 fathoms. At a speed of 8 knots, using a winch with a ¾-h-p. motor, one man can take a sample in 3 minutes in 10 fathoms of water, and in 8 minutes in 100 fathoms.

Models have been built with trap doors to close the tube after taking the sample, and to allow the water in the tube to escape when the sample is taken. These have been discarded as the improvement in the samples was negligible. The sampler can be easily combined with free-falling hydrographic instruments, such as the bathythermograph.

Operation under way improves the ease and accuracy with which the position of a sample may be fixed as the ship can maintain its speed and course. It greatly increases the area covered and the number of samples taken in a given time.

INTRODUCTION

Bottom samples have been used for many years as aids to navigation, and in marine biological investigations. During the past 30 years, the increasing use of sonic and supersonic instruments for sounding and echo ranging has created a demand for bottom-sediment charts to correlate observed variations with bottom materials. More recently, geochemical and sedimentation studies have created a further demand for samples of the ocean floor.

The oldest and simplest equipment for bottom sampling is the sounding lead armed with tallow or grease. This can be used under way at slow speeds, but has many obvious disadvantages. To obtain better bottom samples, dredges and coring tubes have been used.[1] (Reference 1 has a good survey of all types.) These devices require that the ship be stopped, which slows down the work and greatly reduces the precision with which locations may be fixed. The sampler described here can be used while the ship is under way, and will obtain samples of mud, sand, gravel, or coral bottoms, satisfactory for most investigations.

CONSTRUCTION OF SAMPLER

The bottom sampler (Fig. 1) consists of a sample tube, a body weight, a body extension member, and tail fins. The sample tube is made of brass or steel tubing,

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† Department of Geology, Columbia University, New York.

[1] Jack Hough, "Bottom Sampling Apparatus," *Recent Marine Sediments, A Symposium* (Tulsa, Oklahoma: A.A.P.G., 1939), pp. 631–664.

round or square, about 10 inches long, and 2 inches in diameter. The free length inside the tubing of these dimensions must be greater than 6 inches in order to retain the sample; but lengths greater than 8 inches show no improvement in the size of the sample or the ability to retain it. The sample tube forms the nose of the instrument. About 2 inches of the tube overlap on the body weight and are fastened to it with a simple screw or bayonet connection for convenience in cleaning.

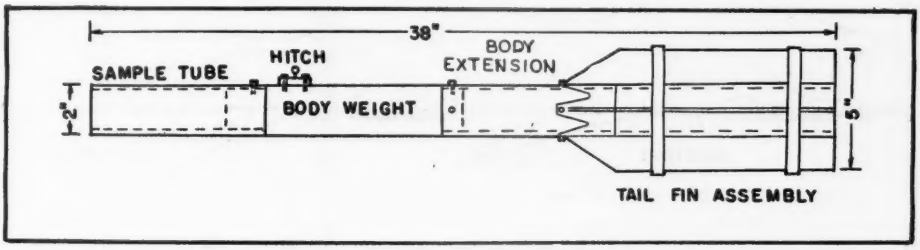

FIG. 1. Underway bottom sampler.

The body weight is a bar of brass or steel, 12 to 15 inches long, with a suitable eye for a cable attachment just behind the sampler tube. The body extension member is made of tubing similar to the sample tube, about 10 inches long, and is attached to the rear end of the body weight. Four tail fins, each with an area of 16 to 20 square inches, are attached in a cross shape at the rear of the body-extension member.

With this arrangement of parts, the sample tube strikes bottom first when the instrument falls freely; but is uppermost while the sampler is being recovered.

The first samplers were built with a shear pin at the forward cable attachment, and a permanent attachment at the tail to facilitate recovery of the sampler if fouled on the bottom. This precaution proved unnecessary and has been abandoned.

OPERATION

Free-fall method.—The operation of the sampler (Fig. 2) is an adaptation of a method first successfully used by Ewing and Vine in 1940 for bathythermograph observations from ships under way. The sampler is allowed to fall freely in the water, and the wire is paid out as required by the fall of the sampler and the movement of the ship. When the sampler strikes bottom, the wire becomes slack. The winch brake is then applied and the sampler quickly rises to its equilibrium level close to the surface, which is determined by the speed of the ship, the amount of wire paid out, and the weight and drag coefficients of the wire and sampler. The strain on the wire from the sudden application of the brake is not excessive, due to the shock-absorbing action of the large curve of the wire. Shortly after the main strain has passed, the winch clutch is engaged and the instrument recovered.

The principal force to be overcome in recovering the instrument is the drag of the wire, so it is desirable to use the smallest wire possible. For instruments weighing 25 pounds or less, and wire lengths up to 2,000 feet, 1/16-inch 7×7 -strand stainless steel airplane control cord, with a breaking strength of 900 pounds, is used.

Electric winch.—A small electric winch is used, with a ¾-h-p. motor for intermittent, and a 1½-h-p. motor for continuous operation. These are stock

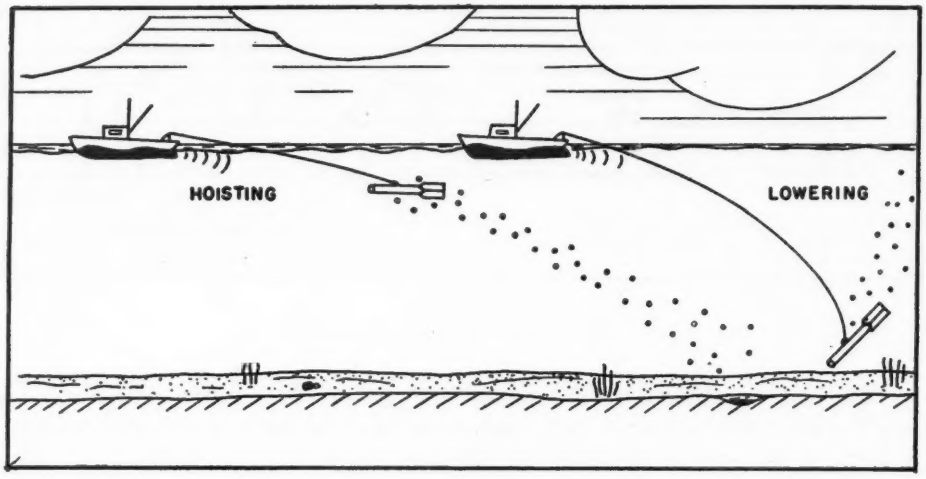

FIG. 2. Method of taking bottom sample.

1,600 r.p.m. motors, geared down, using one countershaft, by a 12-to-1 ratio, so that the winch drum turns at 133 r.p.m. The drum is brass, base diameter 10 inches, width 4 inches, and flange width 2 inches. Brake and clutch are on the same lever, the brake at one extreme, the clutch at the other; on center the clutch is disengaged and only the drum shaft turns as the cable pays out. A counter is attached to the drum shaft to determine the amount of cable paid out at any time.

MODIFICATIONS

Trap-door models.—A sampler has been made with a trap door over the end of the tube to prevent washing of the sample. The door is closed on contact of a trigger with bottom (Fig. 3, Type A). Qualitative comparisons of samples taken in the same area with open-ended and trap-door models show no discernible difference. No quantitative comparisons have been made.

Another model has two trap doors (Fig. 3, Type B), one in the nose and one at an opening in the back end of the sample tube, to allow the water in the tube to escape freely when the sample is taken. No appreciable gain in sample size is observed.

Trap-door models have an advantage in rough weather. If the boat rolls as the instrument is brought out of the water, the tail fins may contact the water

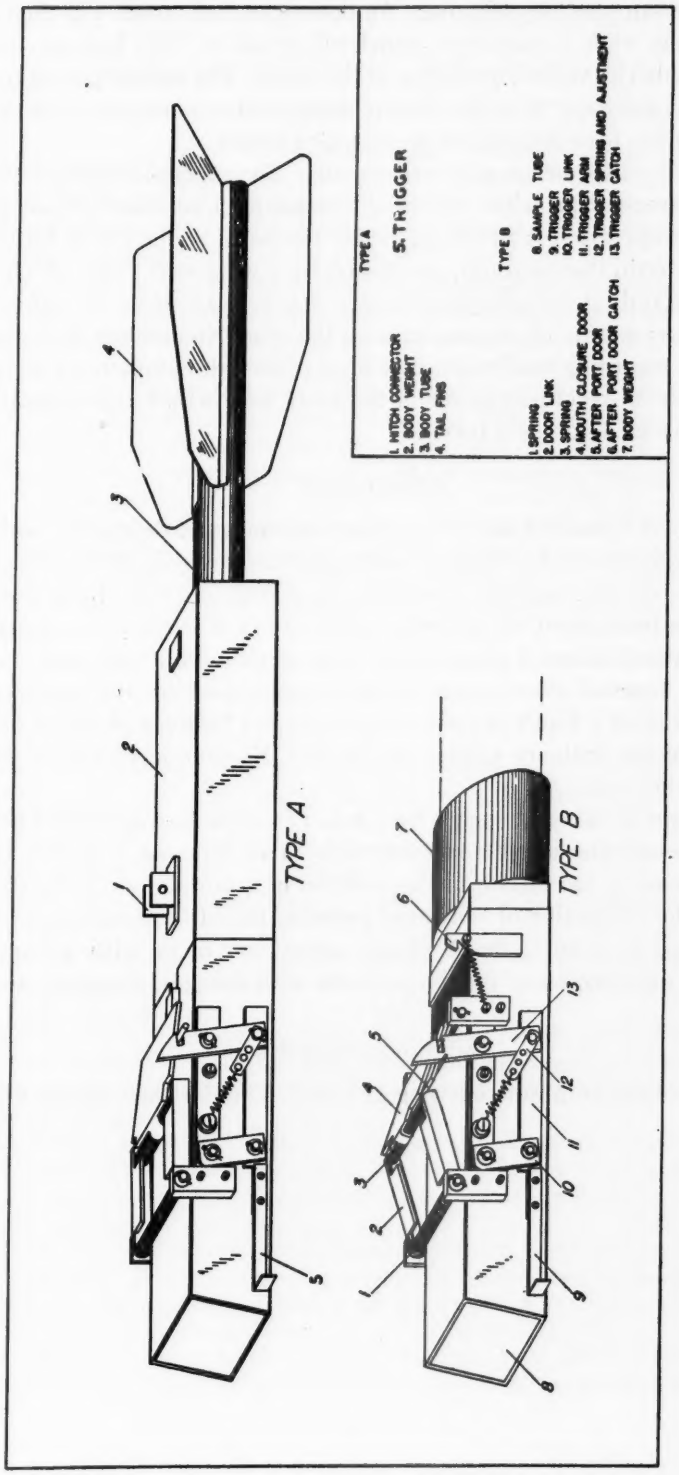

FIG. 3. Design details of two types of bottom samplers.

again, and the sampler may flip over. An open-mouthed model will then usually lose the sample, while a trap-door model will retain it. This loss can, however, largely be avoided by skillful operation of the winch. The advantages of trap-door models are not sufficient to justify their complicated construction, and the open-ended sampler has been adopted as the standard model.

Combination with hydrographic instruments.—Hydrographic instruments operating on the free-fall principle can easily be adapted to take bottom samples, provided their operation is not impaired by the jar of contact with bottom. For example, the bathythermograph, developed by Ewing and Vine, which gives a continuous record of temperature versus depth, was made to take bottom samples by the addition of an open tube on the nose. No damage to the temperature or depth-recording mechanism has been observed. Samplers have also been built with a depth-recording gauge in the body tube which automatically gives the depth at which a sample is taken.

CONCLUSIONS

The samplers described above have been used in water depths to 300 fathoms. Heavier instruments can be designed, and operation in depths of the order of 1,500 fathoms is reasonable. Samples of mud, sand, gravel, and coral have been taken, varying in size from about two pints for soft mud to a tablespoon for coarse gravel; the average size is about ½ pint. Fresh chips of rock have also been recovered.

The only losses of instruments to date were caused by the ship's propellor cutting the wire as a result of poor communication between observer and ship's officers, not of the ordinary yawing of the ship. No samplers have yet been lost by fouling on bottom.

Samples can be taken at speeds from 0 to 12 knots. At a speed of 8 knots, one man can take samples at 3-minute intervals in 10 fathoms of water, and at 8-minute intervals in 100 fathoms. The position of a sample can be located as accurately as the navigation of the vessel permits. Rapid reconnaissance or closely spaced surveys may be made. A recent survey was made with the sampler in one-fifth the time necessary for similar work with dredges, snappers, and coring devices.

ACKNOWLEDGMENTS

Thanks are due to Maurice Ewing and A. C. Vine for their advice and assistance.

DISCUSSIONS AND COMMUNICATIONS

THE OFFSIDE ENERGY PROBLEM IN SEISMIC PROSPECTING

I have just read with much interest the January issue of GEOPHYSICS with its articles on multiple reflection. I have had several similar experiences with definite and indefinite multiples, mainly in California. My greatest difficulties with them have come in localities where genuine deep reflections are interfered with by multiples of shallower horizons, so that the net combination of mixed dips proved awkward to deal with.

I have been wondering whether a similar issue of GEOPHYSICS could not be devoted to the equally common and troublesome problems of offside energy on seismic records arising from a combination of reflection and refraction. In this effect, energy from the shotpoint presumably fans out both along the usual curved-ray paths, and to some extent is refracted laterally along various near-horizontal layers, of various velocities and depths. This lateral energy may encounter a fault at shallow depth, where a velocity contrast returns some of the energy laterally back toward the seismic spread. Apparently this can occur not only from shallow faults, but from river beds, deep irrigation ditches, cliffs, outcropping shallow layers, and other miscellaneous causes. For example, on a water job off Long Beach, California, we got strong energy returns from a known breakwater, these energy arrivals coming in at water velocity, bottom-sand velocity, and several higher velocities supposed to correspond to deeper layers. The earliest possible path gave the first arrival on the records, but some later arrivals appeared to carry more of the energy. Also on this job we got energy back from a known fault on shore over a mile distant, but could not tell whether the path was a normal curved one at depth or was a shallower lateral one.

On a job in the San Fernando Valley, California, we got energy back from a known irrigation ditch at a velocity of 0.6 of the subweathering velocity, and the persons concerned were inclined to regard this as evidence of surface shear waves. The water table was shallow and well defined here, as the valley is an underground city reservoir.

On a job west of Stockton, California, we got strong offside energy, but could not tell for sure whether to blame raised railroad grades, deep irrigation ditches, peat bogs, dipping beds of outcrop, ping rock or possibly shallow faulting.

On a job south of Coalinga, California, strong energy returns were obtained from distances up to a mile away on either side of a known shallow fault.

On a job at Pittsburg, California, energy appeared to return from the edge of the bay north of town.

On a job in Monagas, Eastern Venezuela, energy was definitely returned from shallow faulting, and the resultant apparent dips on the records became badly mixed with nearly as steep real dips from steep shallow bedding.

On a job in Guarico, Venezuela, the offside energy came from shallow faulting of reasonably vertical attitude, and the arrival direction resolved from two components gave a good approximation of the direction of the fault, while the first arrival and probable velocity gave a fair idea of the distance of the fault offside.

The effects above noted have, of course, been best recorded on records without electrical cross-mixing, and with spread distances large enough to allow separation of genuine and offside dips, while spreads of too great geophone intervals have obscured the effects by making the apparent dip too large to notice readily.

Some of the characteristics of offside energy as observed on the records are the following:

(1) The offside energy is usually recorded as lower in frequency than regular reflections for the same record times. This is presumably because the high-frequency components of the disturbance tend to be lost in the strong refraction, leaving the lower-frequency remnants.

(2) The offside effect is most definite when appearing early on a record, say at 0.3 to 0.8 second, especially when in opposition to the first break direction, and thus at the opposite dip from any early-

reflection curvatures. (The early time pins the steep apparent dip down as being due to this type of path.)

(3) The offside energy ordinarily occurs all over the records beyond the time of its initial appearance, supposedly due to repeated arrivals over successively longer paths, with varying velocities.

(4) The offside energy appears where the reflected energy is weak, and is seen in stringers between strong reflections in the early parts of the records, while it may spread all over the tail of a record where no more regular reflected energy is present, but amplifiers are wide open.

(5) The offside energy coming in at a steep apparent dip is free from "normal move-out" effect, and gives a good straight line-up if surface conditions are regular. It is sometimes seen best by lining up half a dozen records or more across a table. Where not wiped out by regular reflected energy, the effect is then seen somewhat spottily distributed.

The subject of offset energy is important and merits further study for the following reasons:

(1) In some cases the existence, direction, and distance of shallow faulting can be ascertained from careful analysis of the data.

(2) The interference arising from offside energy from a fault a mile or more offside may obscure the actual continuity of bedding directly below the spread.

(3) Where the bedding directly below the spread is interrupted by faulting or sharp curvature, the unwary may follow unrelated offside energy trends instead, when these fill in the otherwise blank record.

(4) Where a split record is subject to offside energy, one half may be strongly accentuated where the real dip curvature coincides with the offside energy arrival. The other half of the split may appear angular and discontinuous where the real and offside apparent dips oppose each other. This will adversely affect the appearance of records where the bedding directly below is actually regular and unbroken.

(5) Where the offside effect is strong, electrically mixed records may become hopelessly mixed up.

All this is not intended to be a complete discussion, but should be enough to open up the subject, which I hope may draw some further discussion from others.

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DR. JOHN N. ADKINS TO HEAD NAVY GEOPHYSICS RESEARCH

The Office of Naval Research is announcing another in a series of appointments of active scientists to assist in its research program. This latest appointment brings Dr. John N. Adkins from the Massachusetts Institute of Technology to head the ONR Geophysics Branch, Physical Sciences Division. Dr. Adkins has been granted a year's leave of absence from M.I.T. to assume his duties with the Office of Naval Research.

Dr. Adkins has been assistant professor of Geophysics at M.I.T. since October 1946. The previous five years, during the war, were spent with the Columbia Division of War Research under a National Defense Research Committee contract. His work consisted of geophysical research in terrestrial magnetism, meteorology, and magnetic compensation, which furnished the basis for the important wartime development of magnetic-detection equipment. During this period he spent a year at the Airborne Instruments Laboratory at Mineola, New York, as supervisor of the Antenna Section.

Before the war he was a National Research Fellow in Geophysics at M.I.T., working principally on deformation of the crust of the earth under the action of surface loads.

His degrees, an A.B. in Physics in 1936 and Ph.D. in Seismology in 1939, were conferred by the University of California.

Dr. Adkins will be in charge of the portion of the Navy's extensive basic research program which relates to geophysics. His activities will include directing research in meteorology, oceanography, and

earth sciences. The program in meteorology and its allied sciences is concerned with the studies of atmosphere; the program in oceanography with all aspects of the oceans and their boundaries; and the research in earth sciences with seismology, terrestrial magnetism, atmospheric electricity, gravitation, geography, and geology. This work is being carried on under contract in leading university, government, and industrial laboratories throughout the country. The Geophysics Branch also directs the scientific aspects of various expeditions. These numbered about ten in 1947 and included the Finn Ronne expedition to the Antarctic, an expedition to Helgoland for explosion data, a medical expedition to Africa, an expedition to the Aleutians, and one to Bikini to resurvey effects of the atomic bomb dropped there the previous year.

It is the policy of the Office of Naval Research to bring into its organization scientists who are actively engaged in research work in order to maintain a high level of active scientific skill to benefit the Navy research program. The scientists, upon completion of their leave of absence, return to their laboratories for further active research. The Office of Naval Research plans a steady bilateral flow of personnel from university laboratories to the scientific branches of ONR, and from ONR to the universities to insure a vigorous research program. In this case Dr. Adkins succeeds Dr. Roger R.Revelle, who will return to the Scripps Institution of Oceanography in California, as associate director after a leave of absence from that institution.

PATENTS*

4—ACCELEROMETER

U. S. No. 2,435,231. A. E. McPherson. Iss. 2/3/48. App. 8/3/45.

Acceleration Pickup. An electrical accelerometer having a mass centrally suspended in an annular frame by strain-sensitive filaments which are connected in a Wheatstone bridge circuit.

12—ACOUSTIC MEASUREMENTS

U. S. No 2,434,255. W. L. Bond and G. W. Willard. Iss. 1/13/48. App.5/7/43. Assign. Bell Telephone Laboratories, Inc.

Temperature-Compensated Wave-Propagation Device. An acoustic time-delay apparatus using the propagation time through a liquid medium in which zero temperature coefficient of velocity is attained with a properly proportioned mixture of three components two of which have coefficients of opposite sign.

U. S. No. 2,434,278. W. P. Mason. Iss. 1/13/48. App. 3/4/43. Assign. Bell Telephone Laboratories, Inc.

Submarine Detecting Device. A portable listening device which is temporarily set on the ocean bottom and connected by cable to a ship, the device having a triangular array of piezoelectric hydrophones with the hydrophones in each leg of the array connected to an electrical network so as to have a prismatic effect.

U. S. No. 2,434,644. R. W. Fairweather. Iss. 1/20/48. App. 7/30/45.

Sound-Wave Direction Determinator. A sound-ranging apparatus in which the time differences between receipt of the wave at four microphones at the corners of a square and one at the center are determined by having arrival at the outer microphones start the charging of a condenser and arrival at the center microphone stop the charging and indicating the condenser voltages by connecting to quadrature plates of a c-r tube.

U. S. No. 2,434,667. W. P. Mason. Iss. 1/20/48. App. 6/5/43. Assign. Bell Telephone Laboratories, Inc.

Ultrasonic Prism. A prismatic hydrophone in which 360° of response is attained by using four prisms forming a square and connected to electrical filters whose bands correspond to the various prisms.

U. S. No. 2,434,945. W. P. Mason. Iss. 1/27/48. App. 6/18/43. Assign. Bell Telephone Laboratories, Inc.

Direction-Finding Instrument. A sonic direction finder using a prismatic receiver with narrow-band filters arranged to respond to signals slightly on each side of the main lobe and their ratio or equality indicated by a differential meter.

U. S. No. 2,434,957. D. A. Quarles. Iss. 1/27/48. App. 4/19/44. Assign. Bell Telephone Laboratories, Inc.

Acoustic Indicator for Directional Receivers. Apparatus for determining the direction to a heat source and having a reflector at whose focus a thermistor is eccentrically rotated and connected in series with a synchronously rotating contactor, alternator and head phones so that the correct direction is indicated by a series of signals of uniform intensity.

* Abstracts by O. F. Ritzmann, Gulf Oil Corporation.

16—AIRPLANE FLIGHT INSTRUMENTS

U. S. No. 2,434,270. W. H. T. Holden. Iss. 1/13/48. App. 3/24/44. Assign. Bell Telephone Laboratories, Inc.

Electric Air-Position Indicator. A latitude and longitude indicator having a generator driven at a rate proportional to air speed and two sets of quadrature brushes whose outputs operate the indicators, the polar axis of the generator being adjusted by a compass repeater.

U. S. No. 2,434,694. F. F. Hauptman. Iss. 1/20/48. App. 7/28/45. Assign. Square D Co.

Ground-Speed Indicator. An aircraft ground-speed indicator which is adjusted for barometric pressure obtained from a ground radio station and which has two directional antennas with automatic orienting means and computes the sum of log altitude, log angular velocity about the ground station and log cotangent of the angle of tilt to the ground station.

U. S. No. 2,435,289. E. C. Raney. Iss. 2/3/48. App. 3/5/43. Assign. Ranco Inc.

Altimeter. An altimeter of the aneroid type in which a linear scale is obtained by means of a cam between the capsule and the index which compensates for non-linearity of pressure.

U. S. No. 2,436,417. J. F. Bogen. Iss. 2/24/48. App. 6/29/44.

Inclinometer. An airplane inclinometer having a pendulum on a horizontal shaft to which it is pivoted to allow rotation in a plane parallel to the shaft and avoid the influence of banking of the plane.

U. S. No. 2,436,627. D. Blitz. Iss. 2/24/48. App. 6/24/44. Assign. Radio Corp. of America.

Dually Frequency-Modulated Altimeter. A radio altimeter of the frequency-modulated type having also a low frequency modulation to shift the carrier frequency slightly and cause the so-called "fixed errors" to cancel out.

U. S. No. 2,438,836. I. Wolff. Iss. 3/30/48. App. 7/31/41. Assign Radio Corp. of America.

Pulse-Echo Distance-Measuring System. A pulse-echo radio altimeter in which large distances are indicated from measurements on the pulse envelope and short distances are indicated from measurements on the individual components of the pulse.

48—CASING PERFORATOR

U. S. No. 2,436,118. W. E. Neal. Iss. 2/17/48. App. 5/18/46.

Gun Perforator. A perforating gun in which the barrel units also contain the explosive which is fired by detonation of the previous shot and with a booster charge between units to insure firing.

76—CONTINUOUS WAVE SEISMIC TESTING

U S. No. 2,434,337. F. B. Söderström. Iss. 1/13/48. App. 7/2/42 and 9/10/43. Assign. Vibro-Plus Corp.

Electromagnetic Vibration Motor. A double-acting vibrator having electromagnets arranged to drive the suspended system in alternate directions by undirectional pulses applied to them from an a-c source through rectifiers.

U. S. No. 2,437,983. H. S. Wenander. Iss. 3/16/48. App. 3/24/45. Assign. Vibro-Plus Corp.

Vibrator. A rotating conical pendulum-type of vibrator in which the pendulum is so shaped that the centrifugal forces on the two sides of the rolling surface counterbalance each other so as to reduce the load on the axial suspension bearing.

U. S. No. 2,438,206. W. P. Day. Iss. 3/23/48. App. 10/3/44. Assign. The International Vibration Co.

Rotor for Vibrator Units. An unbalanced rotor having an eccentric steel mass with integral shaft extensions and a lighter metal cast around it in the form of a circular turbine wheel or electric motor armature.

U. S. No. 2,438,755. E. W. Larsen. Iss. 3/30/48. App. 2/15/44. Assign. Western Electric Co., Inc.

Vibrating Apparatus. A mechanically-driven shaking table for vibration-testing of equipment having a control motor which moves a potentiometer to adjust the speed of the main driving motor and also changes the eccentricity of the driving cam so that a regular cycle of vibration changes is executed.

U. S. No. 2,438,756. E. W. Larsen. Iss. 3/30/48. App. 3/27/46. Assign. Western Electric Co., Inc.

Vibrating Apparatus. A mechanically driven shaking table for vibration-testing of equipment which has an automatically controlled adjustment on the eccentric so that tests may be made at different frequencies with constant peak acceleration and which also corrects for elastic effects in the linkage.

108—ECHO SOUNDING

U. S. No. 2,434,667. W. P. Mason. Iss. 1/20/48. App. 6/5/43. Assign. Bell Telephone Laboratories, Inc.

Ultrasonic Prism. A prismatic hydrophone in which 360° of response is attained by using four prisms forming a square and connected to electrical filters whose bands correspond to the various prisms.

U. S. No. 2,436,377. H. B. Briggs, J. B. Johnson and W. P. Mason. Iss. 2/24/48. App. 12/27/43. Assign. Bell Telephone Laboratories, Inc.

Ultrasonic Compressional Wave Transmission. A method of increasing the range of echo sounding in water by transmitting high power in pulses whose duration is shorter than the time required for cavitation to appear.

U. S. No. 2,437,416. T. F. Bludworth. Iss. 3/9/48. App. 11/7/41. Assign. National-Simplex-Bludworth, Inc.

Deep and Shoal Alarm. An echo-sounding apparatus which has a motor-driven cam to initiate repeated depth determinations and associated cams which control relays to operate alarms when the echo arrives sooner or later than predetermined times.

U. S. No. 2,438,580. O. H. Schuck. Iss. 3/30/48. App. 11/6/43. Assign. U.S.A.

Compensator for Doppler Effect. Apparatus for automatically compensating for frequency changes due to motion of the searching ship in echo sounding or ranging and having a condenser in the frequency-determining circuit with one stationary and two automatically adjusted plates, position of one plate being proportional to the velocity of the ship and the other proportional to the cosine of the slight angle.

116—ELECTRIC LOGGING

U. S. No. 2,436,503. J. Y. Cleveland. Iss. 2/24/48. App. 12/22/44. Assign. Socony-Vaccuum Oil Co., Inc.

Delayed Well Logging. A system for delaying the recording of a well-log indication by first recording it on a magnetic tape which is driven by the cable-footage counter and run through a pick-up and put on a permanent record with the desired footage delay so that simultaneous recording from spaced logging devices may be compared as recorded.

U. S. No. 2,436,563. A. Frosch. Iss. 2/24/48. App. 12/27/41. Assign. Standard Oil Development Co.

Well Logging. A system of transmitting several well-logging values over a single conductor cable by using a single oscillator in the well apparatus and modulating the oscillator by each value in succession through a motor-driven commutator and separating the signals at the surface by a synchronously driven commutator.

U. S. No. 2,438,518. R. G. Piety. Iss. 3/30/48. App. 7/25/44. Assign. Phillips Petroleum Co.

Circuit for Measuring Voltage of an Alternating Source. A circuit for eliminating interference of ground currents when measuring small a-c potentials in electric logging while drilling in which the signals are amplified, one or more derivatives taken, and the interference voltage peaks clipped, the clipping level being controlled by the average signal level.

U. S. No. 2,438,747. C. J. Gibbs and J. H. Stein. Iss. 3/30/48. App. 3/4/44 and 9/22/45. Assign. Texaco Development Corp.

Apparatus for Removing Random Fluctuations from Intensity Measurements. A mechanical arrangement for removing small fluctuations of short duration from the indicator of a well-logging instrument by attaching the mirror or pointer to the indicator through a spring-mounted inertia member having limit stops so that large indications of short duration are not removed.

124—ELECTRICAL PROSPECTING

U. S. No. 2,437,697. L. Kalom. Iss. 3/16/48. App. 4/1/46.

Electrical Probe. A surgical metal-locating probe which has a hypodermic needle with an insulated central wire both being cut off at the end at an angle and connected in a flashlight circuit to indicate contact with a metal fragment.

U. S. No. 2,437,134. A. L. Smith. Iss. 3/2/48. App. 12/8/43.

Electrode Assembly for Moisture Meters. An electrode for an electric soil-moisture meter having a metal tube with a slightly smaller insulating tube at its lower end which is closed by a conical electrode connected by a central wire to a meter and battery at the top.

132—ELECTROMAGNETIC PROSPECTING

U. S. No. 2,437,455. S. Berman. Iss. 3/9/48. App. 4/13/43. Assign. Waugh Equipment Co.

Locator. An electromagnetic device for locating metal particles in the human body and having a probe which is the core of a transformer whose secondary voltage is balanced against the secondary voltage of a transformer in the control box and unbalance detected.

136—EXPLOSIVE

U. S. No. 2,434,872. J. Taylor and J. Whetstone. Iss. 1/20/48. App. 11/6/42 and 2/12/44. Assign. Imperial Chemical Industries, Ltd.

Manufacture of Compact Combustible Explosive Charges. A combustible explosive for generating gas pressure to operate mechanical devices and which contains ammonium nitrate, an oxidizable material, a chromate sensitizer and an ammonium nitrate fusion-promoting ingredient.

U. S. No. 2,435,116. F. H. Armstrong. Iss. 1/27/48. App. 11/28/45. Assign. Armstrong Coal Break Co.

Blasting Cartridge. A non-explosive blasting cartridge having a chamber which is loaded by connecting to a source of high pressure gas and a trigger-controlled quick-operating valve for releasing the gas from the chamber.

140—FLAW DETECTOR

U. S. No. 2,434,203. C. Farrow. Iss. 1/6/48. App. 9/22/43. Assign. Republic Steel Corp.

Method and Apparatus for Magnetic Testing. An a-c magnetic-testing method using a single primary and two series-connected secondaries with their common point grounded and together feeding two separate impedance-bridge circuits whose outputs are fed to quadrature plates of a c-r. tube.

U. S. No. 2,435,134. E. G. Forssell. Iss. 1/27/48. App. 9/18/44. Assign. W. H. Miner, Inc.

Method of Detecting Flaws in Tubular Steel Castings. A method of x-radiographing tubular steel castings by placing a strip of film against the inner surface and progressively exposing portions of the outer surface to x-rays.

U. S. No. 2,435,680. T. T. Goldsmith, Jr. and E. R. Mann. Iss. 2/10/48. App. 2/26/44. Assign. Allen B. DuMont Laboratories, Inc.

Apparatus for Electrically Testing Material. A material-testing system in which the test coil or condenser is in the circuit of a feedback oscillator adjusted just under the oscillation point and periodically energized and the oscillation decay exhibited on a c-r-tube screen as a cyclograph which is periodically blocked-out to detect phase shifts.

U. S. No. 2,435,985. W. H. Stewart and J. W. Millington. Iss. 2/17/48. App. 8/12/42. Assign. Sun Oil Co.

Electromagnetic Apparatus for Detecting Flaws in Suspended Pipe. A flaw detector or use on drill pipe and having an a-c excited coil through which the pipe passes and within which it is centered by rollers, the coil being tuned and connected in an a-c bridge circuit whose unbalance due to a flaw is detected.

U. S. No. 2,436,615. D. E. Stearns. Iss. 2/24/48. App. 7/5/43.

Apparatus for Detecting Imperfections in Insulating Materials. Electric spark apparatus for locating defects in an insulating coating on pipe and having a high voltage transformer which discharges an oscillatory circuit to the pipe through the defect, a condenser connected between the pipe and ground being connected to an electronic indicator.

U. S. No. 2,436,918. T. de Forest. Iss. 3/2/48. App. 7/22/42. Assign. Magnaflux Corp.

Magnetic-Inspection Apparatus. A device for applying dry iron powder to a magnetized specimen by an air gun supplied from a powder hopper and air compressor.

148—FLOW METER

U. S. No. 2,434,837. R. O. Cornett. Iss. 1/20/48. App. 1/11/44.

Null-Type Differential Micromanometer. A differential micromanometer for use with a Venturi meter in which the pressures are transmitted to chambers containing a liquid and connected by a capillary tube with an air bubble to indicate motion of the liquid, the position of the bubble being restored to an index by a calibrated displacement screw in one of the chambers.

U. S. No. 2,435,043. H. Lehde and W. T. Lang. Iss. 1/27/48. App. 10/6/44. Assign. Control Instrument Co., Inc.

Device for Measuring Rate of Fluid Flow. A flow meter for electrically conducting liquids in which distortion of the field from two opposed a-c excited coils caused by flow of the conducting fluid is picked up by a third coil.

152—FLUORESCENCE LOGGING

U. S. No. 2,435,843. W. P. Rand. Iss. 2/10/48. App. 3/18/47. Assign. Gulf Research & Development Company.

Method of Examining Earth Substance by Means of Ultraviolet Illumination. A method of analyzing rock cuttings by dropping them into a shallow dish of non-fluorescent oil solvent and observing characteristics of the fluorescent streamers or plumes produced in the solvent.

168—GAS ANALYSIS

U. S. No. 2,437,720. R. A. Ackley. Iss. 3/16/48. App. 6/14/43. Assign. Republic Flow Meters Co.

Method of and Apparatus for Measuring the Composition of Gas. A method of determining the oxygen content of flue gas or engine exhaust gas by mixing it with a combustible gas, burning the mixture in air with a flame and measuring the temperature of the flame.

172—GEOCHEMICAL PROSPECTING

U. S. No. 2,437,045. E. E. Roper. Iss. 3/2/48. App. 4/24/44. Assign. Stanolind Oil and Gas Co.

Determination of Hydrocarbon Concentration in Soil Samples. A method of soil analysis in which successive portions of the soil sample are each exposed to an atmosphere of an inert gas containing known concentrations of hydrocarbons until equilibrium is reached and the atmosphere adjusted until there is no change in hydrocarbon concentration of the atmosphere.

180—GRAVIMETER

U. S. No. 2,438,758. C. C. Leach. Iss. 3/30/48. App. 12/29/43. Assign. One-half to M. Boulicault and R. J. Miller.

Liquid Column Level. A liquid level for leveling large surfaces using two cups connected by a hose full of mercury and electrical contacts in the cups to indicate which cup is at a lower level and also having an electromagnetic vibrator at the center of the hose to speed up the mercury flow.

192—INCLINOMETER

U. S. No. 2,435,934. F. M. Varney and J. A. Varney. Iss. 2/10/48. App. 1/29/40.

Signalling Clinograph. A pendulum inclinometer which is spring set when circulation is stopped and which signals the degree of inclination by a plunger which passes constrictions to produce pressure-impulse signals.

200—LEVEL INDICATOR

U. S. No. 2,438,330. L. B. Winton. Iss. 3/23/48. App. 10/14/42. Assign. Jerguson Gage & Valve Co.

Liquid-Level Indicator. An arrangement for steadying the boiler gage glass on a ship by introducing in the lower gage line a chamber containing mercury and with the two connecting tubes ending just above the mercury surface so that tilting of the ship introduces a differential mercury pressure which restrains excessive fluctuations in the gage.

208—LOGGING WHILE DRILLING

U. S. No. 2,438,518. R. G. Piety. Iss. 3/30/48. App. 7/25/44. Assign. Phillips Petroleum Co.

Circuit for Measuring Voltage of an Alternating Source. A circuit for eliminating interference of ground currents when measuring small a-c potentials in electric logging while drilling in which the signals are amplified, one or more derivatives taken and the interference voltage peaks clipped, the clipping level being controlled by the average signal level.

216—MAGNETIC COMPASS

U. S. No. 2,434,324. H. Lehde. Iss. 1/13/48. App. 10/6/44. Assign. Control Instrument Co., Inc.

Earth-Inductor Compass. A vibrating coil-type earth-inductor compass in which the coil is vibrated by Rochelle salt crystals excited from an oscillator which also excites one phase of an orienting servo-motor whose other phase is excited by the emf generated in the coil.

U. S. No. 2,435,276. E. L. Holmes. Iss. 2/3/48. App. 8/14/42 and 8/14/43. Assign. One-half to Henry Hughes & Son Ltd.

Magnetic Field Indicating Means. A flux-valve compass having two toroidal cores with their pole pieces at right angles, the cores being energized one-eighth cycle apart and with pickup coils on the pole pieces connected to a phasemeter energized at double frequency.

U. S. No. 2,437,132. A. T. Sinks. Iss. 3/2/48. App. 11/17/43. Assign. General Electric Co.

Remote-Indicating Compass. A remote-indicating compass having suspended magnets surrounded by an annular saturable core which is wound with a distributed exciting winding and two or more polyphase pickup coils connected to a similar repeater.

U. S. No. 2,437,506. L. P. Crossman. Iss. 3/9/48. App. 6/16/43. Assign. Monroe Calculating Machine Co.

Repeator Compass. A photoelectric follow-up for a magnetic compass which also drives integrators which record on an odograph.

U. S. No. 2,437,692. E. W. Hart. Iss. 3/16/48. App. 5/3/45.

Magnetic Compass. A compass having four magnetic needles, the outer ones being shorter than the inner ones and with their pole strengths adjusted so that sextantal or decantal deviations on shipboard are eliminated.

220—MAGNETIC LOGGING

U. S. No. 2,436,039. C. H. Fay. Iss. 2/17/48. App. 1/11/45. Assign. Shell Development Co.

Magnetic-Field Gradient Measurement. A magnetic-gradient meter having two spaced coplanar oppositely connected coils mounted on an elastic suspension and carrying a mirror which reflects a beam of light onto a photocell, the photocell output being amplified and fed back to the suspended coils to sustain oscillation, indication being obtained from the amplification required to maintain oscillation.

224—MAGNETIC RECORDER

U. S. No. Re. 22,970. (Orig. No. 2,356,145) Iss. 2/10/48. App. 6/12/40, 8/22/44 and 9/18/46. Assign. Magnetone, Inc.

Magnetic Sound-Recording and Reproducing. A magnetic-tape recording and play-back device having several sections and with controls for using it as a voice mirror and arranged so that the operator may select either some of his own or model reproductions.

U. S. No. 2,435,871. M. Camras. Iss. 2/10/48. App. 8/26/44. Assign. Armour Research Foundation.

Recording and Reproducing Head for Wire Recorders. A magnetic recorder head having a plate with a crowned and grooved edge along which the wire passes and with two slits leading to holes which carry the erasing coil and the recording coil.

U. S. No. 2,436,829. R. I. Roth. Iss. 3/2/48. App. 1/31/45. Assign. International Business Machines Corp.

Bipolar Magnetic Control Record. A control record made of a paper sheet impregnated with powdered Alnico and having magnetized spots which have N- and S-poles slightly separated in the direction of record motion.

U. S. No. 2,438,222. W. P. Lear. Iss. 2/23/48. App. 5/22/45. Assign. Lear, Inc.

Magnetic Sound-Translating System. A magnetic wire recorder with storage and rewind reels, reversing motor controlled by the operating switches and brakes on the reel whose tensions are controlled by the direction of winding.

228—MAGNETIC TESTING

U. S. No. 2,434,203. C. Farrow. Iss. 1/6/48. App. 9/22/43. Assign. Republic Steel Corp.

Method and Apparatus for Magnetic Testing. An a-c magnetic-testing method using a single primary and two series-connected secondaries with their common point grounded and together feeding two separate impedance-bridge circuits whose outputs are fed to quadrature plates of a c-r tube.

U. S. No. 2,435,985. W. H. Stewart and J. W. Millington. Iss. 2/17/48. App. 8/12/42. Assign. Sun Oil Co.

Electromagnetic Apparatus for Detecting Flaws in Suspended Pipe. A flaw detector for use on drill pipe and having an a-c-excited coil through which the pipe passes and within which it is centered by rollers, the coil being tuned and connected in an a-c bridge circuit whose unbalance due to a flaw is detected.

U. S. No. 2,438,506. A. G. Ladrach. Iss. 3/30/48. App. 11/25/43. Assign. Niles-Bement-Pond Co.

Electromagnetic Gauge. A variable air-gap a-c impedance-type thickness-variation detector for sheet steel, the detector being mounted on a micrometer screw and held slightly above the top surface of the moving sheet so that it can operate at the same nominal air gap for any thickness of sheet.

232—MAGNETOMETER

U. S. No. 2,436,039. C. H. Fay. Iss. 2/17/48. App. 1/11/45. Assign. Shell Development Co.

Magnetic-Field Gradient Measurement. A magnetic-gradient meter having two spaced coplanar oppositely connected coils mounted on an elastic suspension and carrying a mirror which reflects a beam of light onto a photocell, the photocell output being amplified and fed back to the suspended coils to sustain oscillation, indication being obtained from the amplification required to maintain oscillation.

U. S. No. 2,436,394. W. P. Maltby and R. H. Park. Iss. 2/24/48. App. 6/6/41.

Magnetic Detector. A detector for a magnetic mine and having a permalloy bar with a coil wound along its length and with flux gathering flanges on the ends whose radius is half the length of the bar.

U. S. No. 2,437,374. R. E. Burroughs. Iss. 3/9/48. App. 5/15/45. Assign. Eastman Kodak Co.

Magnetic Field Measuring Device. An apparatus for detecting relative motion by having a magnet on one part and an electron tube with a split anode on the other, motion of the magnet causing shift of electron beam from one anode to the other.

U. S. No. 2,438,372. L. I. Mendelsohn. Iss. 3/23/48. App. 10/1/45. Assign. General Electric Co.

Precision Magnetometer. A suppressed-zero mechanical indicator for measuring the strengths of permanent magnets and having an armature and pointer on a rotatable shaft with a biased control spring, the scale having a suppressed zero and pointer stop.

244—MICROPHONE

U. S. No. 2,434,143. C. Chilowsky. Iss. 1/6/48. App. 4/17/43 and 9/25/43.

Supersonic Signal Transmitter and Receiver. A supersonic hydrophone having a sound-transparent material on one side of a solid plastic with preoriented piezoelectric crystals suspended in it and a sound-reflecting material with a backing plate on the other side of the piezoelectric plastic.

U. S. No. 2,434,285. R. L. Peek, Jr. Iss. 1/13/48. App. 2/27/43. Assign. Bell Telephone Laboratories, Inc.

Compressional Wave Translating Device. A magnetostrictive hydrophone having a laminated

cylindrical core with portions cut out to leave legs which carry the energizing coils, the free ends of the legs engaging the vibrator base.

U. S. No. 2,434,926. H. C. Hays. Iss. 1/27/48. App. 3/8/37.

Underwater Sound Transmitter or Receiver. A submarine-signaling transmitter or receiver having a transducer immersed in oil inside a case with a rubber sound-transparent window and having the transducer vibrator resiliently suspended from its mounting.

U. S. No. 2,435,920. L. R. Burroughs. Iss. 2/10/48. App. 9/20/43. Assigns Electro-Voice Manufacturing Co., Inc.

Balanced Granular Microphone. A double-button carbon microphone whose diaphragm has a frusto-conical projection in the center which fits into a similarly shaped rear button.

U. S. No. 2,436,384. H. Fletcher, J. F. Müller and K. D. Swartzel, Jr. Iss. 2/24/48. App. 12/19/41. Assign. Bell Telephone Laboratories, Inc.

Sound-Recording Device. An anti-aircraft shell containing a sound recorder, the recording drum being driven by outward centrifugal flow of fluid from a power cylinder and the sound recorded by a stylus attached to a diaphragm.

U. S. No. 2,437,088. G. M. Giannini. Iss. 3/2/48. App. 3/22/43 and 10/8/45. Assign. Automatic Electric Laboratories, Inc.

Microphone Assembly. A pair of oppositely directed electromagnetic microphones in a single case arranged to be supported on the periscope of a submarine for operation as a sound-direction finder.

276—PERMEABILITY TESTING

U. S. No. 2,437,935. E. M. Brunner and E. S. Mardock. Iss. 3/16/48. App. 5/7/45. Assign. Shell Development Co.

Radiological Measurement of the Permeability of Porous Media. A method of determining permeability by forcing a polyphase fluid through a confined sample of the medium, measuring the pressure drop and determining the saturation of the medium to a hydrogen-containing phase by its effect in slowing down neutron radiation.

280—PHOTOGRAPHIC LOGGING

U. S. No. 2,433,971. H. A. Adams. Iss. 1/6/48. App. 2/28/44. Assign. One-tenth to A. H. Cassidy.

Underwater Image-Transmitting Apparatus. A mobile underwater-illuminating and scene-viewing apparatus operated at the end of a cable from a ship, the scene being transmitted to the ship by television.

288—PRESSURE GAUGE

U. S. No. 2,434,837. R. O. Cornett. Iss. 1/20/48. App. 1/11/44.

Null-Type Differential Micromanometer. A differential micromanometer for use with a Venturi meter in which the pressures are transmitted to chambers containing a liquid and connected by a capillary tube with an air bubble to indicate motion of the liquid, the position of the bubble being restored to an index by a calibrated displacement screw in one of the chambers.

U. S. No. 2,437,371. A. C. Allen. Iss. 3/9/48. App. 2/4/44. Assign. Stewart-Warner Corp.

Absolute Pressure Gauge. A gauge for measuring absolute pressure in the intake manifold of a supercharged aircraft engine, the pressure being applied to the inside of a bellows which is in an evacuated container and maintained extended by a spring.

U. S. No. 2,437,440. D. L. Rigden. Iss. 3/9/48. App. 1/4/45.

Balanced Pressure Gage and Switch. A mercury-column pressure gage in which the force on a small piston is balanced by the pressure of the mercury on a larger piston.

U. S. No. 2,438,228. R. A. Osten. Iss. 3/23/48. App. 9/14/45. Assign. Wyandotte Chemicals Corp.

Manometer. A closed U-tube type of pressure gauge in which the mercury is easily replaced having two U-types with their upper ends connected and the bends made of capillary tubes and a stopcock at the top of one arm.

304—RADIOACTIVITY LOGGING

U. S. No. 2,436,008. S. Krasnow and L. F. Curtiss. Iss. 2/17/48. App. 10/24/39 and 1/19/43.

Signalling System for Radioactive Well Logging. A radioactivity well-logging system which has a Geiger-Muller tube and an amplifier in the detector, the amplifier operating a relay which controls current fed down the cable and recorded at the surface.

U. S. No. 2,436,503. J. Y. Cleveland. Iss. 2/24/48. App. 12/22/44. Assign. Socony-Vacuum Oil Co., Inc.

Delayed Well Logging. A system for delaying the recording of a well-log indication by first recording it on a magnetic tape which is driven by the cable-footage counter and run through a pickup and put on a permanent record with the desired footage delay so that simultaneous recording from spaced logging devices may be compared as recorded.

U. S. No. 2,438,747. C. J. Gibbs and J. H. Stein. Iss. 3/30/48. App. 3/4/44 and 9/22/45. Assign. Texaco Development Corp.

Apparatus for Removing Random Fluctuations from Intensity Measurements. A mechanical arrangement for removing small fluctuations of short duration from the indicator of a well-logging instrument by attaching the mirror or pointer to the indicator through a spring-mounted inertia member having limit stops so that large indications of short duration are not removed.

308—RADIOACTIVITY MEASUREMENTS

U. S. No. 2,434,297. M. J. Test and S. Krasnow. Iss. 1/13/48. App. 10/1/41.

Radiation-Intensity Meter. A gamma-ray intensity meter using a Geiger-Muller tube mounted in a standard tube base and indicating the frequency of pulses through the G-M tube and also having a gas discharge tube whose oscillations are controlled to operate an alarm.

U. S. No. 2,436,084. B. L. Weller, Iss. 2/17/48. App. 11/27/43. Assign. U.S.A.

Ionization Chamber. An evacuated detector for measuring penetrating radiation having a collecting cylinder and a high potential cylinder with an electrostatic guard between them and also around the collecting cylinder insulator.

U. S. No. 2,437,476. H. M. Parker. Iss. 3/9/48. App. 7/8/44. Assign. U.S.A.

Differential Twin-Chamber Neutron Meter. An apparatus for measuring neutron intensity in the presence of gamma-rays having two ionization chambers with their collecting electrodes connected together and to an electroscope, the chambers containing different gases and charged with opposite sign and arranged so that the pair may be rotated 180° to interchange their locations.

U. S. No. 2,437,935. E. M. Brunner and E. S. Mardock. Iss. 3/16/48. App. 5/7/45. Assign. Shell Development Co.

Radiological Measurement of the Permeability of Porous Media. A method of determining permeability by forcing a polyphase fluid through a confined sample of the medium, measuring the pres-

sure drop and determining the saturation of the medium to a hydrogen-containing phase by its effect in slowing down neutron radiation.

312—RADIO NAVIGATION

U. S. No. 2,436,376. R. Bown. Iss. 2/24/48. App. 3/31/44. Assign. Bell Telephone Laboratories, Inc.

System for Transmitting Intelligence. A Loran system in which the repetition frequencies of signals from the pairs of fixed stations bear a vernier relation to each other so that when displayed on a common screen, the time relation of the sets of pulses is easily determined.

U. S. No. 2,436,479. D. G. C. Luck. Iss. 2/24/48. App. 12/22/45. Assign. Radio Corp. of America.

Course-Indicator System for Radio Ranges. A course indicator for radio navigation which shows the sense as well as the angle of a doubly modulated range beacon signal.

316—RADIO RANGING

U. S. No. 2,434,263. H. Diamond, F. W. Dunmore and W. S. Hinman, Jr. Iss. 1/13/48. App. 12/22/38. Assign. U.S.A.

Determining Upper Air-Wind Conditions by Radio-Direction Findings. A method of measuring the vertical angle of incidence of a radio wave by raising the receiver and its antenna above the surface of the earth and observing null points due to interference between the direct wave and the wave reflected from the surface of the earth.

U. S. No. 2,434,917. M. Fuchs. Iss. 1/27/48. App. 11/6/43. Assign. Federal Telephone and Radio Corp.

Mechanical Modulator. A system for modulating high-frequency electrical energy carried by a coaxial transmission line by mechanically varying the coupling between the shield and ground or between two sections of shield.

U. S. No. 2,434,977. R. H. Worrall. Iss. 1/27/48. App. 8/31/37.

Radio Direction Finder. A radio direction finder having two dipole antennas at the ends of a rotatable arm and having the power for the receivers supplied by a generator driven from a vertical shaft which is driven by a motor at the base.

U. S. No. 2,435,569. W. L. Barrow. Iss. 2/10/48. App. 8/5/41. Assign. Sperry Gyroscope Co., Inc.

Synchronized Radio Transmission. A radio ranging-system utilizing a narrow band receiver of the superheterodyne type supplied with a heterodyning frequency derived from the transmitter through a modulator and converter.

U. S. No. 2,435,615. R. H. Varian, W. W. Hansen and J. R. Woodyard. Iss. 2/10/48. App. 9/30/41. Assign. The Board of Trustees of the Leland Stanford Junior University.

Object Detecting and Locating System. A radar system in which several frequencies are transmitted, reflections received and mixed with the transmitted frequency to produce Doppler beat notes whose phase may be compared to determine the distance to the reflecting object.

U. S. No. 2,436,672. R. C. Sanders, Jr. Iss. 2/24/48. App. 7/26/43. Assign. Radio Corp. of America.

Frequency-Modulated Radio Distance-Measuring System and Indicator. A radio-locator system transmitting a cyclically frequency-modulated wave, using the reflected wave to produce a beat-frequency signal which is indicated by a tuned device and which is periodically damped at the discontinuities at the end of each frequency-modulation sweep.

U. S. No. 2,437,695. K. G. Jansky. Iss. 3/16/48. App. 8/40/43. Assign. Bell Telephone Laboratories, Inc.

Three-Dimension Radio Direction Finder. An absolute-type radio direction finder using a phase-

comparison method with vertical antennas at three corners of a square, the phase adjusters being coupled to d-c potentiometers whose voltages are applied to quadrature plates of a c-r tube indicator.

324—RECORDER

U. S. No. 2,434,531. J. A. Wilson and J. J. Heigl. Iss. 1/13/46. App. 4/21/44. Assign. Standard Oil Development Co.

High-Speed Recording System. A system for making a spark record on electrosensitive recording paper from a galvanometer deflection by directing the galvanometer beam onto a rotating mirror and to a photocell which effects a spark from a stationary bar on one side of the paper to a synchronously rotating helix on the other side of the paper.

U. S. No. 2,436,384. H. Fletcher, J. F. Müller and K. D. Swartzel, Jr. Iss. 2/24/48. App. 12/19/41 Assign. Bell Telephone Laboratories, Inc.

Sound-Recording Devices. An anti-aircraft shell containing a sound recorder, the recording drum being driven by outward centrifugal flow of fluid from a power cylinder and the sound recorded by a stylus attached to a diaphragm.

344—SEISMOGRAPH AMPLIFIER

U. S. No. 2,434,223. R. H. Park. Iss. 1/6/48. App. 3/15/44. Assign. American Cyanamid Co.

High-Gain Amplifer. A multi-stage amplifier for a flickering-beam spectrophotometer in which the shielding of the first stage, its cathode, and the shielding of succeeding stages are separately grounded on the integrating sphere.

U. S. No. 2,438,217. C. H. Johnson. Iss. 3/23/48. App. 6/30/44. Assign. Socony-Vacuum Oil Co., Inc.

Method for Elimination of Periodic Stray Signals from Seismic Signals. A system for eliminating 60-cycle pickup from a seismograph amplifier by diverting a portion of the signal, amplifying it, filtering out the steady-state signal and introducing distortion to accentuate odd harmonics, and then feeding it back into the amplifier at some other point 180° out of phase to effect cancellation.

360—SEISMOGRAPH PROSPECTING

U. S. No. 2,438,526. C. H. Waterman. Iss. 3/30/48. App. 4/18/41. Assign. Submarine Signal Co.

System for Determining the Direction of a Source of Sound. A highly directive listening system using two microphones with a small angle between their axes, their outputs being separately amplified, rectified and combined as a sensitivity control to both amplifiers so that the signal in one channel causes positive feedback in its own amplifier and negative feedback in the other.

368—SEISMOGRAPH TIMING

U. S. No. 2,435,903. O. F. Ritzmann. Iss. 2/10/48. App. 12/9/44. Assign. Gulf Research & Development Co.

Method and Apparatus for Exhibiting Seismograph Signals. A system for transmitting timing and shot moment on a single channel by having the build-up of the firing current gradually suppress but not obliterate the timing signal with sudden increase of timing signal indicating the shot moment.

380—SEISMOMETER TESTING

U. S. No. 2,438,755. E. W. Larsen. Iss. 3/30/48. App. 2/15/44. Assign. Western Electric Co., Inc.

Vibrating Apparatus. A mechanically-driven shaking table for vibration-testing of equipment having a control motor which moves a potentiometer to adjust the speed of the main driving motor and also changes the eccentricity of the driving cam so that a regular cycle of vibration changes is executed.

U. S. No. 2,438,756. E. W. Larsen. Iss. 3/30/48. App. 3/27/46. Assign. Western Electric Co., Inc.

Vibrating Apparatus. A mechanically-driven shaking table for vibration-testing of equipment which has an automatically controlled adjustment on the eccentric so that tests may be made at different frequencies with constant peak acceleration and which also corrects for elastic effects in the linkage.

388—SHOT MOMENT RECORDING

U. S. No. 2,435,903. O. F. Ritzmann. Iss. 2/10/48. App. 12/9/44. Assign. Gulf Research & Development Co.

Method and Apparatus for Exhibiting Seismograph Signals. A system for transmitting timing and shot moment on a single channel by having the build-up of the firing current gradually suppress but not obliterate the timing signal with sudden increase of timing signal indicating the shot moment.

412—SPECIFIC GRAVITY MEASUREMENTS

U. S. No. 2,434,098. G. S. Bays. Iss. 1/6/48. App. 9/10/42. Assign. Stanolind Oil and Gas Co.

Density-Indicating Apparatus. A device for measuring the density of a flowing fluid which has two diaphragms at different depths in the fluid and an indicator actuated by the difference in diaphragm deflection.

U. S. No. 2,437,247. K. Fischer. Iss. 3/9/48. App. 5/15/44.

Specific-Gravity Indicator. A flow meter in which the fluid is passed through a rotameter tube having two separate metering floats, one float being sensitive to rate of flow and insensitive to variations in specific gravity and viscosity and the other float being sensitive to rate of flow and specific gravity and insensitive to viscosity, the specific gravity being indicated by the difference in position of the two floats.

416—SPECTROGRAPH

U. S. No. 2,436,104. A. W. Fisher and W. B. Warren. Iss. 2/17/48. App. 5/11/44. Assign. Fisher Scientific Co.

Photoelectric Apparatus for Spectrographic Analysis. An analyzing spectrograph in which photocells are placed at the positions of lines of an unknown element and of the internal standard and the energy received by the photocells is integrated over equal periods of time and indicated.

U. S. No. 2,437,323. J. J. Heigl and J. A. Wilson. Iss. 3/9/48. App. 5/26/44. Assign. Standard Oil Development Co.

Apparatus for Instantaneously Indicating on an Oscilloscope Screen the Absorption Spectrum of a Substance. A split-beam absorption spectrometer in which the adjusting mirror or prism is mechanically vibrated and the difference of the detecting photocell responses amplified and connected to the vertical plates of a c-r tube whose horizontal plates are connected to the vibrating oscillator.

420—SPECTROPHOTOMETER

U. S. No. 2,434,223. R. H. Park. Iss. 1/6/48. App. 3/15/44. Assign. American Cyanamid Co.

High-Gain Amplifier. A multi-stage amplifier for a flickering-beam spectrophotometer in which the shielding of the first stage, its cathode, and the shielding of succeeding stages are separately grounded on the integrating sphere.

U. S. No. 2,435,175. G. L. Buc and E. I. Stearns. Iss. 1/27/48. App. 8/8/46. Assign. American Cyanamid Co.

Flickering-Beam Spectrophotometer for the Measurement of Bronze. A spectrophotometer for measuring the bronze effect of inks and pigments by mounting the pigment surface in one of the

spectrometer beams so that the reflectance angle may be varied and returning the beam to its original path by means of a prism moved with the surface.

U. S. No. 2,435,176. G. L. Buc and E. I. Stearns. Iss. 1/27/48. App. 8/8/46. Assign. American Cyanamid Co.

Flickering Beam Spectrophotometer for the Measurement of Bronze. A spectrophotometer for measuring the bronze effect of pigments by mounting the pigment surface inside the integrating sphere so that the beam strikes at an angle of incidence which is large enough to produce the bronze effect.

428—STRAIN GAUGE

U. S. No. 2,434,547. T. E. Brown, Jr. Iss. 1/13/48. App. 7/27/45. Assign. Westinghouse Electric Corp.

Electrical Gage Circuits. An indicator circuit for a variable reactance-type electric strain gage in which each reactor winding is connected in series with a transformer with a full-wave rectifier connected to its secondary and the algebraic sum of the rectifier outputs indicated.

U. S. No. 2,434,628. E. E. Simmons, Jr. Iss. 1/13/48. App. 11/18/43.

Method of Making Strain Gages. A method of making filament-type strain gages by winding the filament around a piece of plastic, covering with a removable membrane and applying heat and pressure to embed the filament in the plastic.

U. S. No. 2,435,254. W. Ramberg. Iss. 2/3/48. App. 9/25/45.

Dynamic Strain Pickup. A transducer in which the moving element is mounted on an elliptic spring which bears against a resistance element and shorts out varying portions of the resistance.

U. S. No. 2,436,459. D. D. Symmes. Iss. 2/24/48. App. 5/31/43. Assign. The American Steel and Wire Co. of N. J.

Rope-Tension Measuring Device. A cable tensiometer in which the transverse deflection is transmitted to the indicator by a flexible band around a cam sector so shaped that a linear scale is obtained.

U. S. No. 2,437,639. F. K. Floyd. Iss. 3/9/48. App. 8/19/43. Assign. Metron Instrument Co.

Electrical Measuring Apparatus. A variable air-gap reluctance-type electric comparator gage having four gage coils in the arms of an impedance bridge with full wave rectifiers at the junction of the arms so that the unbalance may be indicated on a d-c meter.

U. S. No. 2,438,205. J. E. Coates. Iss. 3/23/48. App. 9/15/45. Assign. Douglas Aircraft Co., Inc.

Measuring Instrument. A method of making a bonded electrical strain gauge by painting or printing on an insulating backing a grid of conducting paint on which a thin film of metal is deposited by electroplating.

U. S. No. 2,438,589. E. C. Walker. Iss. 3/30/48. App. 8/30/46. Assign. Curtiss-Wright Corp.

Electric Strain Gage. A filament-type electric strain gage in which the wire is wound back and forth in two lines each making an angle to the gage axis whose tangent squared is equal to Poisson's ratio of the material to which the gage is applied.

432—SUBMARINE LOCATOR

U. S. No. 2,433,971. H. A. Adams. Iss. 1/6/48. App. 2/28/44. Assign. One-tenth to A. H. Cassidy.

Underwater Image-Transmitting Apparatus. A mobile underwater-illuminating and scene-viewing apparatus operated at the end of a cable from a ship, the scene being transmitted to the ship by television.

U. S. No. 2,434,278. W. P. Mason. Iss. 1/13/48. App. 3/4/43. Assign. Bell Telephone Laboratories, Inc.

Submarine Detecting Device. A portable listening device which is temporarily set on the ocean bottom and connected by cable to a ship, the device having a triangular array of piezoelectric hydrophones with the hydrophones in each leg of the array connected to an electrical network so as to have a prismatic effect.

436—SUBMARINE SIGNALING

U. S. No. 2,434,143. C. Chilowsky. Iss. 1/6/48. App. 4/17/43 and 9/25/43.

Supersonic Signal-Transmitter and Receiver. A supersonic hydrophone having a sound-transparent material on one side of a solid plastic with preoriented piezoelectric crystals suspended in it and a sound-reflecting material with a backing plate on the other side of the piezoelectric plastic.

U. S. No. 2,434,285. R. L. Peek, Jr. Iss. 1/13/48. App. 2/27/43. Assign. Bell Telephone Laboratories, Inc.

Compressional Wave Translating Device. A magnetostrictive hydrophone having a laminated cylindrical core with portions cut out to leave legs which carry the energizing coils, the free ends of the legs engaging the vibrator base.

U. S. No. 2,434,900, R. Black, Jr. and F. F. Romanow. Iss. 1/27/48. App. 7/14/43. Assign. Bell Telephone Laboratories, Inc.

Sonic Translating Device. A hydrophone having two hemispheres each carrying an inertia-type transducer and with one hemisphere surrounded by a heavy case with only a very small opening to the sea water and containing a small air chamber so that the hydrophone system has a secondary resonance at a high frequency.

U. S. No. 2,434,926. H. C. Hays. Iss. 1/27/48. App. 3/8/37.

Underwater Sound-Transmitter or Receiver. A submarine-signaling transmitter or receiver having a transducer immersed in oil inside a case with a rubber sound-transparent window and having the transducer vibrator resiliently suspended from its mounting.

U. S. No. 2,435,253. E. E. Turner, Jr. Iss. 2/3/48. App. 5/13/40 and 2/17/43. Assign. Submarine Signal Co.

System for Sound Ranging. A submarine-signaling system using two pickup units at right angles each having pickup surfaces one-half wave length apart and with each unit connected to quadrature plates of a c-r tube.

U. S. No. 2,435,587. W. R. Harry. Iss. 2/10/48. App. 7/14/43. Assign. Bell Telephone Laboratories, Inc.

Compressional Wave Signaling Device. A hydrophone having a rigid hollow sphere with a rubber cover and freely mounted in a framework, the inside of the sphere having three perpendicular sets of inertia-type transducers.

U. S. No. 2,435,595. W. P. Mason. Iss. 2/10/48. App. 2/19/42 and 8/19/43. Assign. Bell Telephone Laboratories, Inc.

High-Power Compressional Wave Radiator. A high-power submarine-signaling radiator using Rochelle salt driving elements and having next to the elements a viscous medium like castor oil which can handle more power without cavitation and allowing the energy to spread before reaching the outer cover and passing into the sea water at a lower power density.

U. S. No. 2,436,377. H. B. Briggs, J. B. Johnson and W. P. Mason. Iss. 2/24/48. App. 12/27/43. Assign. Bell Telephone Laboratories, Inc.

Ultrasonic Compressional Wave Transmission. A method of increasing the range of echo sounding in water by transmitting high power in pulses whose duration is shorter than the time required for cavitation to appear.

U. S. No. 2,437,270. R. L. Peek, Jr. Iss. 3/9/48. App. 11/5/43. Assign. Bell Telephone Laboratories, Inc.

Magnetostrictive Compressional Wave Transmitter or Receiver. A magnetostrictive transducer having a rectangular core and a permanent magnet adjacent one leg of which is provided with a short portion of restricted cross-section so as to equalize the polarizing flux in the two parallel magnetic paths.

U. S. No. 2,437,282. E. E. Turner, Jr. Iss. 3/9/48. App. 11/18/42. Assign. Submarine Signal Co.

Electroacoustic Transducer. A magnetostrictive vibrator having a series of magnetostrictive tubes with one end free and the other end mounted on the radiating plate and having the coils and polarizing magnets mounted on a backing plate.

U. S. No. 2,438,526. C. H. Waterman. Iss. 3/30/48. App. 4/18/41. Assign. Submarine Signal Co.

System for Determining the Direction of a Source of Sound. A highly directive listening system using two microphones with a small angle between their axes, their outputs being separately amplified, rectified and combined as a sensitivity control to both amplifiers so that the signal in one channel causes positive feedback in its own amplifier and negative feedback in the other.

U. S. No. 2,438,580. O. H. Schuck. Iss. 3/30/48. App. 11/6/43. Assign. U.S.A.

Compensator for Doppler Effect. Apparatus for automatically compensating for frequency changes due to motion of the searching ship in echo sounding or ranging and having a condenser in the frequency-determining circuit with one stationary and two automatically adjusted plates, position of one plate being proportional to the velocity of the ship and the other proportional to the cosine of the sight angle.

456—THERMAL PROSPECTING

U. S. No. 2,434,957. D. A. Quarles. Iss. 1/27/48. App. 4/19/44. Assign. Bell Telephone Laboratories, Inc.

Acoustic Indicator for Directional Receivers. Apparatus for determining the direction to a heat source and having a reflector at whose focus a thermistor is eccentrically rotated and connected in series with a synchronously rotating contactor, alternator and headphones so that the correct direction is indicated by a series of signals of uniform intensity.

U. S. No. 2,435,519. W. A. Tolson. Iss. 2/3/48. App. 2/14/44. Assign. Radio Corp. of America.

Image-Forming Heat Detector. A device for converting a heat image into an optically visible image by focusing the heat waves onto the convex side of a thin cellulose acetate diaphragm whose concave side is coated with evaporated aluminum and forms a concave optical mirror, distortions in the diaphragm by heat being observable as irregularities in the concavity of the mirror.

460—THERMOMETER

U. S. No. 2,437,085. J. Evans. Iss. 3/2/48. App. 3/12/43. Assign. Radio Corp. of America.

Heat-Detection Device. A heat detector having a thin diaphragm over an air chamber and in which motion of the diaphragm is detected either by changing capacity to an adjacent plate or by changing inductance in an adjacent high-frequency coil.

468—TIME INTERVAL METER

U. S. No. 2,435,753. W. Richter and W. H. Elliot. Iss. 2/10/48. App. 10/7/43. Assign. Cutler-Hammer Inc.

Apparatus for Recording the Duration of a Transient Effect. A circuit for measuring the duration of the arc at closing or opening of contact points in which the arc voltage unbalances a bridge which charges a condenser whose voltage is applied to a recording vacuum-tube voltmeter circuit.

U. S. No. 2,436,725. M. Morrison. Iss. 2/24/48. App. 10/23/43.

Electronic Timing Apparatus. An electronic telegraph repeater or receiver which uses a local constant-frequency source driving a pair of multivibrators which supply two gas discharge tubes whose grids are controlled from the input signal.

472—TIMEPIECE TESTING

U. S. No. 2,437,929. W. O. Bennett, Jr. Iss. 3/16/48. App. 6/18/44. Assign. Hamilton Watch Co.

Timing Apparatus. A watch rate-determining apparatus in which ticks of the watch are amplified and used to drive a reed having a broad resonance and the reed vibrations used to drive a synchronous motor whose speed is compared with a standard timing system through a differential speed indicator.

484—TRANSDUCER

U. S. No. Re. 22,971. (Orig. No. 2,416,978) C. F. Burgess. Iss. 2/10/48. App. 1/22/45, 3/4/47 and 8/8/47. Assign. O. W. Storey.

Capillary Transducer. An electromechanical transducer having a circuit including the interface of a capillary electrometer and a slender rod which transmits vibrations from an external diaphragm to the interface.

U. S. No. 2,433,898. W. E. Gilman. Iss. 1/6/48. App. 11/23/42 and 2/1/46. Assign. Permoflux Corp.

Magnetostrictive Vibrator Unit. A magnetostrictive vibrator having a bar mounted at its mid-point and annular driving units around each free end.

U. S. No. 2,434,337. F. B. Söderström. Iss. 1/13/48. App. 7/2/42 and 9/10/43. Assign. Vibro-Plus Corp.

Electromagnetic Vibration Motor. A double-acting vibrator having electromagnets arranged to drive the suspended system in alternate directions by unidirectional pulses applied to them from an a-c. source through rectifiers.

U. S. No. 2,434,648. W. D. Goodale, Jr. and T. J. Pope. Iss. 1/20/48. App. 6/2/43. Assign. Bell Telephone Laboratories, Inc.

Compressional Wave Translating Device. A piezoelectric supersonic projector for submarine signaling having an array of quartz crystal layers with alternate layers mounted at right angles and energized 90° out of phase to give a circular propagation pattern.

U. S. No. 2,434,682. C. T. Zahn. Iss. 1/20/48. App. 8/18/44.

Device for Production of Underwater Sound Fields. A mechanically-driven underwater sound source having a rotor with radial pipes rotating in a housing with an annular opening, centrifugal action causing cavitation inside the housing.

U. S. No. 2,434,842. W. C. Eaves. Iss. 1/20/48. App. 1/1/42. Assign. Eaves Sound Projectors, Inc.

Pneumatic Sound-Producing Device. A modulated air-stream sound head having a heating coil in the housing and valve head to prevent condensation and frost formation.

U. S. No. 2,434,908. P. K. Chatterjea and C. J. Scully. Iss. 1/27/48. App. 1/13/43 and 1/12/44. Assign. International Standard Electric Corp.

Thermionic Amplifier. A circuit for the output stage of a radio receiver and having in the plate circuit of the tube a thermistor operated so as to generate harmonics in the low-frequency range.

U. S. No. 2,435,140. W. R. Koch. Iss. 1/27/48. App. 11/30/45. Assign. Radio Corp. of America.

Signal-Translating Apparatus. A capacity-type phonograph pickup in which linear capacity change with stylus motion is attained by using a curved stationary plate and the correct air gap is maintained by mounting the stationary plate on material of the same thermal expansion as the reed.

U. S. No. 2,435,487. R. Adler. Iss. 2/3/48. App. 2/1/43. Assign. Zenith Radio Corp.

Electromechanical Vibrator. An electromechanical oscillating system of very high frequency in which a loop in a high-frequency circuit induces eddy currents in a small adjacent conducting body located in a permanent magnetic field, the body being set into resonant oscillation by the forces between the eddy currents and the field.

U. S. No. 2,435,534. W. C. Eaves. Iss. 2/3/48. App. 7/25/42. Assign. Eaves Sound Projectors, Inc.

Electropneumatic Sound Reproducer. A sound head of the air-flow type in which the flow of air is valved by a counter-balanced angularly oscillating grid driven by current in a rotating voice coil.

U. S. No. 2,435,535. W. C. Eaves. Iss. 2/3/48. App. 1/10/44. Assign. Eaves Sound Projectors, Inc.

Sound-Projecting Apparatus. A sound projector made by using a number of exponential horns opening into a combined bell section.

U. S. No. 2,435,996. C. W. Baird. Iss. 2/17/48. App. 4/1/43.

Detecting and Alarm System. An alarm system in which mechanical disturbances of a fence are detected by electromagnetic transducers and in which failure alarm is obtained by also supplying the transducers with ac at a lower frequency than any to be detected and the low-frequency signal balanced out of the detecting circuit.

U. S. No. 2,436,946. F. B. Tatro. Iss. 3/2/48. App. 4/10/41. Assign. V. A. Hamilton.

Capacity-Type Phonograph Pickup. A condenser-type phonograph pickup in which the stylus is mounted so as to move interlocking condenser plates having strips of soft rubber dielectric between them.

U. S. No. 2,437,270. R. L. Peek, Jr. Iss. 3/9/48. App. 11/5/43. Assign. Bell Telephone Laboratories, Inc.

Magnetostrictive Compressional Wave Transmitter or Receiver. A magnetostrictive transducer having a rectangular core and a permanent magnet adjacent, one leg of which is provided with a short portion of restricted cross-section so as to equalize the polarizing flux in the two parallel magnetic paths.

U. S. No. 2,437,282. E. E. Turner, Jr. Iss. 3/9/48. App. 11/18/42. Assign. Submarine Signal Co.

Electroacoustic Transducer. A magnetostrictive vibrator having a series of magnetostrictive tubes with one end free and the other end mounted on the radiating plate and having the coils and polarizing magnets mounted on a backing plate.

U. S. No. 2,437,639. F. K. Floyd. Iss. 3/9/48. App. 8/19/43. Assign. Metron Instrument Co.

Electrical Measuring Apparatus. A variable air-gap reluctance-type electric comparator gage having four gage coils in the arms of an impedance bridge with full-wave rectifiers at the junction of the arms so that the unbalance may be indicated on a d-c meter.

U. S. No. 2,438,110. W. H. Brattain. Iss. 3/23/48. App. 7/28/43. Assign. Bell Telephone Laboratories, Inc.

Electrical Translating Materials and Devices and Method of Making Them. A detector for ultra-high frequency radio waves having a crystallized layer of thermally deposited silicon on a tantalum backing strip and with the surface of the silicon treated with lead oxide.

U. S. No. 2,438,111. R. H. Campbell. Iss. 3/23/48. App. 11/26/45. Assign. Webster Electric Co.

Stylus for Sound Reproduction. A phonograph needle having close to its point a U-shaped integral spring with closely spaced parallel legs to raise the natural frequency of the needle and reduce mechanical noise.

490—VEHICLE

U. S. No. 2,438,277. R. E. Fife and R. E. Fife, Jr. Iss. 3/23/48. App. 1/3/45.

Oil-Well Mast. A truck-mounted portable pulling rig having an extensible frame which is pivoted at the bottom so that it can be reclined while moving and with hydraulic cylinders in each side of the frame for raising the crown.

492—VIBROMETER

U. S. No. 2,433,845. H. C. Hayes and H. M. Trent. Iss. 1/6/48. App. 11/28/41.

Sound-Operated Relay System. A trigger circuit containing a relay and a chattering-contact impulse switch which opens the circuit when disturbed.

U. S. No. 2,435,031. J. R. Burns and J. M. Whitmore. Iss. 1/27/48. App. 2/16/44. Assign. General Motors Corp.

Detonation Pickup. A magnetostrictive vibration pickup which may be mounted on the outside of an engine cylinder to detect detonation, the unit having a permanent magnet core of magnetostrictive material to which the vibration is imparted and a coil surrounding the core.

U. S. No. 2,435,254. W. Ramberg. Iss. 2/3/48. App. 9/25/45.

Dynamic Strain Pickup. A transducer in which the moving element is mounted on an elliptic spring which bears against a resistance element and shorts out varying portions of the resistance.

496—VISCOSIMETER

U. S. No. 2,434,349. T. A. Cohen. Iss. 1/13/48. App. 2/26/43. Assign. Wheelco Instruments Co.

Viscosity-Measuring Apparatus. A falling-ball viscosimeter in which the time of fall is determined by detecting the passage of the ball between pairs of condenser plates at the top and bottom and having the condenser circuits trip relays.

U. S. No. 2,437,194. B. S. Harrington. Iss. 3/2/48. App. 5/31/45. Assign. Armour and Co.

Consistometer. A device for determining the temperature at which an oil congeals and having a wheel and crosshead which moves a thermometer and baffle up and down in a cylindrical container full of the oil so that on congealing, the oil and container are lifted against a contact which rings an alarm.

500—VOLTMETER

U. S. No. 2,438,518. R. G. Piety. Iss. 3/30/48. App. 7/25/44. Assign. Phillips Petroleum Co.

Circuit for Measuring Voltage of an Alternating Source. A circuit for eliminating interference of ground currents when measuring small a-c potentials in electric logging while drilling in which the signals are amplified, one or more derivatives taken and the interference voltage peaks clipped, the clipping level being controlled by the average signal level.

516—WELL SIGNALING

U. S. No. 2,435,934. F. M. Varney and J. A. Varney. Iss. 2/10/48. App. 1/29/40.

Signalling Clinograph. A pendulum inclinometer which is spring set when circulation is stopped and which signals the degree of inclination by a plunger which passes constrictions to produce pressure-impulse signals.

U. S. No. 2,436,008. S. Krasnow and L. F. Curtiss. Iss. 2/17/48. App. 10/24/39 and 1/19/43.

Signalling System for Radioactive Well Logging. A radioactivity well-logging system which has a Geiger-Muller tube and an amplifier in the detector, the amplifier operating a relay which controls current fed down the cable and recorded at the surface.

U. S. No. 2,436,563. A. Frosch. Iss. 2/24/48. App. 12/27/41. Assign. Standard Oil Development Co.

Well Logging. A system of transmitting several well-logging values over a single conductor cable by using a single oscillator in the well apparatus and modulating the oscillator by each value in succession through a motor-driven commutator and separating the signals at the surface by a synchronously driven commutator.

520—WELL SURVEYING

U. S. No. 2,436,047. P. W. Martin. Iss. 2/17/48. App. 6/15/45.

Tool Indicator. A device which may be lowered into a well with tools to indicate depth and which has scrapers which set up vibrations on passing the pipe joints and a microphone which picks up the vibrations which are then electrically transmitted to the surface so that pipe lengths may be counted.

U. S. No. 2,436,417. J. F. Bogan. Iss. 2/24/48. App. 6/29/44.

Inclinometer. An airplane inclinometer having a pendulum on a horizontal shaft to which it is pivoted to allow rotation in a plane parallel to the shaft and avoid the influence of banking of the plane.

U. S. No. 2,436,503. J. Y. Cleveland. Iss. 2/24/48. App. 12/22/44. Assign. Socony-Vacuum Oil Co., Inc.

Delayed Well Logging. A system for delaying the recording of a well-log indication by first recording it on a magnetic tape which is driven by the cable-footage counter and run through a pickup and put on a permanent record with the desired footage delay so that simultaneous recording from spaced logging devices may be compared as recorded.

U. S. No. 2,438,293. H. G. Livingston. Iss. 3/23/48. App. 7/12/43. Assign. Eastman Oil Well Survey Co.

Means for Bottom-Hole Orientation. A device for finding the high side of a hole and having a pendulum with a light source which shines through a fixed radial slot onto a photocell which actuates a relay and operates an electric hammer to make a sound which can be picked up at the surface.

REVIEWS

SPECIAL REVIEWS COMMITTEE

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Industrial Experimentation by K.A. Brownlee. Brooklyn, N. Y.: Chemical Publishing Co., Inc., 1947. Pp. 151.

This remarkable little book is an attempt by the author to present the material developed largely by R. A. Fisher and associates in a long series of papers and summarized well in the two books by Fisher, namely "Statistical Methods for Research Workers" and "The Design of Experiments." Fisher's direct interest was in planning agricultural experiments so that conclusions could be precisely stated with precisely associated measures of validity. Mr. Brownlee makes many references to Fisher's works but attempts to either leave out "theory" or illustrate the theory with numerical examples. His particular target is industrial chemistry. He appears to feel, correctly, that chemical engineers can utilize the developments that have been carried forward by agricultural investigators in the "design of experiments."

In the first ten short chapters (68 pages in all) the problems are described in such a way as to introduce the reader to the bearing of statistical methods on the industrial chemical problems. The statistical jargon is introduced very well indeed in a rough sort of way—this being probably the best way to help his readers to pick up a bewildering multiplicity of new ideas without "bogging down" at some "way point." The question regarding how much "theory" the "practical" manager and planner can do without has been given a compromise answer by including certain parts and excluding certain other parts of the theory. Since people's needs vary so much, his answer given this way is sure to be wrong, but it seems to be a good compromise.

The first ten chapters are listed below:

I. Introduction. Experimental Error and Designs to Reduce Error.
II. Fundamental Statistical Conceptions. Terminology, Probability, Significance Tests, Measures of Variability.
III. Significance of Means. Variability of Means. Sample Size.
IV. The Comparison of Variances. Second look at "Variance."
V. The χ^2 Test (Chi-squared). How likely are observations to be the result of random variations necessarily present?
VI. The Poisson Distribution. Rare occurrences.
VII. The Analysis of Variance. Third look at "Variance."
VIII. The Quality Control Chart.
IX. The Relation Between Two Variables. Correlation.
X. Multiple Correlation.

The remaining chapters, mainly by illustrative numerical problems followed through in detail, carry the subject forward if the reader isn't lost in the numerical details or the reasons for the numerical steps. They are: XI. The General Analysis of Variance; XII. Miscellaneous Aspects of the Analysis of Variance; XIII. Balanced Incomplete Blocks; XIV. Confounding; and XV. General Conclusions. These are followed by five tables that are highly useful if one wishes to use the methods.

What is the value of this book and its subject matter to geophysicists? The value is considerable and perhaps may be illustrated by reference to exploration by soil-analysis methods. How can a field program be planned to insure objectivity of conclusions? Do soil gas samples vary seasonally, daily,

too much in the immediate neighborhood of each sample place, too much due to soil or vegetation variations, etc.? What conclusions can be drawn and how reliable are they?

Basically the question is: what can be gained by detailed planning of observational procedures to insure that the ultimate conclusions can be evaluated, measured so far as their objective reliabilities are concerned?

That a detailed systematic consideration of this problem has value can hardly be doubted. In industry the real question is: how much planning (at what cost) can be justified taking into account the cost of alternative courses of procedure? Any mature investigator carries on considerable conscious planning and some very able ones appear to proceed intuitively in a very "sure-footed" manner through a very complicated course of investigation. The answer depends partly on the nature of the data; the problem, partly on the experience of the investigator, and partly on the scale of the work. Very costly investigitions demand more planning than small scale, inexpensive, short-time projects.

The methods (Fisher's mainly) outlined in this book should be used usually in any evaluation of a semi-empirical method, such as soil analysis, as an exploration procedure, where uncontrolled causes of variation of results are present to a probably serious extent. It is most unfortunate that these methods were not used in all of the soil-analysis investigations made in the past.

The average reader will need Fisher's two books (loc. cit.) for reference. The print is annoyingly small. Formulas and symbols are not italicized as they should be. The book can be skimmed to find what parts appear to fit the reader's practical needs. Details can be dug out of examples or out of Fisher's treatments.

C. HEWITT DIX

Magnetische Messungen an der Mangan-Eisenerzlagerstaette Fianell (Val Ferrera) (Magnetic Measurements Over the Manganese Ore Deposits in Fianell (Val Ferrera) Switzerland) by Ernst Niggli. *Schweizerische Mineralogische und Petrographische Mitteilungen*, Band XXVI, Heft 2 (1946), Pp. 92–115.

This paper represents a very valuable addition to the literature pertaining to the correlation of anomalies found in magnetic surveys with the geologic and mineralogic factors causing them. Major positive ΔZ magnetic anomalies as large as 1,113 gammas were measured over out-cropping manganese ores, although the magnetic field observed over the iron ore in this area was essentially normal. It was therefore possible to trace the manganese ore lenses within the ore body itself by magnetic means.

A detailed mineralogic investigation was conducted in the laboratory including the use of powder diagrams to discover the cause of this phenomenon. The iron ores proved to be very weakly magnetized, having a volume susceptibility of less than 0.0005, whereas the susceptibility of the manganese ore ranged from 0.002 to 0.091 and exhibited typical ferromagnetic properties including hysteresis. The mineral responsible for the strong magnetism of the manganese ores proved to be jacobsite, $(MnFe)_3O_4$, which together with brownite comprises the manganese ores of this district. The presence of the jacobsite was discovered during the analysis of brownite polished sections. A detailed mineralogic analysis indicated that of the many specimens of manganese ore from this area which were investigated, 80 percent contained an appreciable amount, i.e., more than 2 percent, of jacobsite, and were highly magnetic.

A compilation of all the available quantitative data on the magnetic properties of manganese minerals and ores available in the scientific literature is also presented, together with a detailed discussion. If similar mineralogic, spectrographic and petrographic studies were to accompany the majority of magnetic field studies, more rapid progress would be made in the art of the interpretation and analysis of magnetic surveys and their associated anomalies than has occurred in the past.

R. A. GEYER

Praktische Geophysik (Applied Geophysics) by Dr. Phil. Otto Meisser, Dresden and Leipzig: Theodor Steinkopff, 1943. Pp. 368.

Very little information is available in this book that cannot be found in some of the standard

foreign handbooks and compendia on pure and applied geophysics such as Gutenberg's *Handbuch der Geophysik*, Angenheister's *Angewandte Geophysik*, and Tams' *Grundzuege der Physikalischen Verhaeltnisse der Festen Erde*. Its chief value lies in the fact that some of the more basic and fundamental concepts of the major fields of geophysical prospecting can be found summarized in the various chapters pertaining to these subjects. Although the author stresses in his preface the fact that the subject matter of the book is directed primarily to the fields of applied geophysics, certain of the chapters are devoted to discussions of meteorology, astronomy and atmospheric electricity.

A number of tables usually found in textbooks of this sort occur at the end of the book. However, a few are of sufficient interest and novelty to merit mention in some detail. For example, one table summarizes the probable physical constants of the atmosphere to a height of 100 kilometers including such factors as temperature, pressure, density, molecular velocity, number of molecules, and collision numbers. The last factor is defined as the number of molecules colliding within a cubic centimeter during a period of one second. The velocity of propagation of waves having a frequency of 20 to 25 cycles for 24 different types of unconsolidated sediments and soils is listed in another table. The velocity of longitudinal and transverse waves, together with certain calculated elastic constants, is tabulated for samples of sands of different grain size and moisture content. Although these tables are also available in the literature, the references cited are rather obscure and the tables for the most part can more easily be obtained by referring to this book.

R. A. GEYER

The Thickness of Ocean Sediments Measured by a Reflection Method by Waloddi Weibull. (Goeteborgs Kungl. Vetenskaps- Och Vitterhets-Samhaelles Handlingar. Sjaette Foeljden.) Ser. B, Band 5, No. 4 (1947). Pp. 3–17.

This paper describes the preliminary results obtained during the expedition of the Swedish research ship "Skagerak" in the Gullmarfjord and the Mediterranean to determine the thickness of ocean sediments using seismic-acoustic methods. Certain theoretical considerations involved are described in some detail, together with an analysis of a schematic oscillogram, although no actual records showing the reflections from interfaces are shown. The method is essentially that introduced by Behm in 1912 for echo sounding where an explosive charge is detonated below the water surface and the sound waves reflected from the bottom are recorded. The author contends that echoes could be observed from reflecting surfaces situated several thousand meters below the relatively unconsolidated sediments, assuming that explosive charges of sufficient magnitude and/or receiving apparatus of sufficiently high sensitivity and amplification were to be used. Between Algiers and Naples a sedimentary layer 8,000 feet thick was recorded by this method in about 10,000 feet of water during a cruise in that area in 1945. Subsequently a preliminary analysis of the results obtained during the cruise of the "Albatross" during 1947 using essentially the same equipment and methods indicated that the sediments overlying the basement complex in certain areas of the Atlantic Ocean varied between 1,000 and 3,000 feet.

Dr. J. B. Hersey of the Woods Hole Oceanographic Institution and Professor Maurice Ewing of Columbia University have also conducted similar surveys within the past year or two using a method employing the same fundamental principles. Although final results are not available at the present time, the presence of relatively unconsolidated deposits as thick as 9,000 feet are indicated in the western Atlantic. The use of methods of this type on marine expeditions should do much to increase the knowledge of the areal distribution and thickness of the relatively unconsolidated deposits existing in the world oceans.

R. A. GEYER

National Research Council, Canadian Geophysical Bulletin, Vol. 1. Issued Quarterly by the Associate Committee on Geodesy and Geophysics, Ottawa, 1 July–30 September 1947.

This issue of the quarterly report is similar in organization and content to the previous ones, although much of the available space is devoted to the fields of meteorology, hydrology, and terrestrial magnetism including a short discussion of atmospheric ionization. A review in some detail of seismo-

logical activities is presented including a progress report on the rock-burst seismic survey project and the refraction survey for the determination of the depth of overburden in North York township in Ontario. A large number of earthquakes were recorded during the summer in the course of continuing the former project and the information gained will be valuable in the study of travel times across the Canadian shield. It is planned to continue the operation of the two observation stations. One hundred shotpoints were fired this summer while conducting the latter survey designed to locate relatively unconsolidated deposits in the bedrock which might be potential water supply reservoirs. In fourteen places the depth of overburden determinations were checked with the drill and a maximum error of 3 percent was observed. In some instances the depth of overburden was as much as 101 feet. On the basis of these preliminary checks the continuation of this survey appears to be justified.

The M.A.D. equipment acquired by the N.R.C. from the United States Navy has been modified into apparatus suitable for airborne magnetic surveys. One instrument was installed and the area from 76°00′ to 76°30′ W and from 44°45′ to 45°30′ N was mapped. Topographical maps on a scale of one mile to the inch are available for this 1,200 square mile area and several known magnetite deposits occur within its borders. It is planned to install another unit in a Canso airplane for use next summer in making more extensive surveys.

The magnetic project involving the compilation of data from ground surveys by mining companies reported in some detail in the first report of the N.R.C. Quarterly is continuing. The material is now being prepared for publication and it is anticipated that no serious difficulties will be encountered in connection with obtaining the necessary permission for publication. A summary of magnetic and electrical surveys made by private companies is also included in detail showing the name of the company, the area, the number of readings and the acreage involved. The section on geodesy is confined primarily to a detailed bibliography of references pertaining to gravity and geodetic surveys made in Canada.

A summary of the geophysical prospecting activities for oil is also included listing in detail the number of seismograph, gravity meter, and magnetometer parties active in the field. Estimates of expenditures are also given with seismic costs averaging $15,000 or more depending upon terrain, gravity meter parties $5,000 a month, and magnetometer parties approximately $1,000 a month when operated in conjunction with other geophysical parties. An estimated $2,700,000 has been spent for geophysical surveys during 1947 exclusive of aerial magnetometer prospecting.

R. A. GEYER

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*Marine Seismic Exploration along the Southern Coast of the Apsheron Peninsula,** by A. A. Tsvetaev and N. I. Shapirovsky. *Applied Geophysics*, No. 1 (1945). Pp. 77–82. (Organ of Federal United Geophysical Trust; Scientific Research Institution of Applied Geophysics; People's Commisariat of Petroleum, U.S.S.R.)

Experimental marine seismic exploration was commenced in 1941, and since that time considerable progress has been made. The seismic apparatus has been adapted for marine observations; a technique has been worked out, and a considerable amount of data has been accumulated.

The actual recording of reflected waves at sea is accomplished in essentially the same manner as on land. In marine exploration, the observing station is located on a motor barge, while fishing boats are used for shooting operations. In most cases, the survey is carried out by the method of continuous profiling.

The seismometers are fastened to wooden floats. Such a floating seismometer is located at a predetermined distance above the sea bottom. This distance is maintained by the length of the line connecting the float to a weight resting on the bottom. The electrical cables, which also rest on the bottom are of the two-conductor copper, steel-armored, rubber-insulated type.

The method described permits the recording of reflected waves along a coastal strip of a width up to about 10 miles, where the depths do not exceed 50–70 feet. Along numerous sectors of the coast,

* Caspian Sea, near the city of Baku.—Ed.

reliable reflections were obtained, which possessed well-developed amplitude and phase characteristics. In such cases marine seismograms have an appearance differing but slightly from ordinary land records.

Depending on the location, the period of the reflected waves varies between 0.015 and 0.03 second. Reflections are obtained at times corresponding to depths ranging from 1,500 feet to 13,000 feet.

Near shores and in shallow water, low-frequency disturbance appears on the records and the corresponding waves have been termed "bottom waves." They resemble the surface waves encountered in land seismology. The period of the "bottom waves" is 0.04–0.05 second, while the apparent velocity of propagation is 1,300 to 1,600 ft/sec. It was established that the recorded intensity of this vibration decreases as the distance of the floating seismometer from the bottom is increased.

"Bottom waves" are eliminated by means of high-pass filtering which, in the case of this particular recording channel, is accomplished by the seismometer, transformers, and the filter sections between cascaded amplifier stages.

At certain locations, high-frequency disturbance is recorded, the period varying between 0.01 and 0.002 second. When charges of ordinary size are used, these vibrations persist for 10 seconds or more. Their intensity is so large that it becomes impossible to detect the concealed reflected energy itself. No success is yet claimed in establishing a connection between the character of these high-frequency events and the peculiarities of the terrain (depth of sea, characteristic of bottom, depth of geologic structure, etc.). Experimentation establishes that these vibrations originate in the water medium. It does not appear likely that present records will yield information as to a possible preferred direction of their arrival.

In the practice of marine seismology, the high-frequency events are called reverberating waves in analogy to the well-known acoustic phenomenon of a sound persisting in closed space after the action of the source has stopped; this is due to multiple reflections from surfaces bounding the space.

In order to suppress these secondary events on the records, the amplifiers at the central recording station are provided with low-pass filter sections.* Apparatus of this kind yielded records which were quite free of events having a frequency higher than 100 c.p.s.† In this manner the field of application of the method of reflected waves in water has been considerably enlarged. However, there exist sectors in which the records show events having frequencies of about 100 c.p.s., and these persist for some 10 seconds or more.

Thus it appears that the problem of eliminating the reverberating events is not completely solved as yet. The development of a more perfect filter seems required. However, it is quite possible that conditions may arise when the vibrations caused by wanted and unwanted energy may possess the same frequency spectrum with the intensity of the latter exceeding that of the former. Under such circumstances, filtering will fail and other methods of attack will have to be introduced, in particular, methods of directional selectivity.

The use of multiple detectors in marine work was limited by the lack of a sufficient number of stable and waterproof seismometers.

When recording reflected waves at sea, a very interesting phenomenon is observed, namely the appearance of secondary arrivals. These appear rather strongly after the initial break and follow one another at intervals of 0.1–0.3 second. Cases of one and two secondary arrivals have been observed. Increasing the charges increases the time interval between arrivals in the latter case. These secondary arrivals complicate seismic interpretations, disturb the reproducibility from shot to shot, and, when occurring with sufficient energy, may lead to false reflections. Therefore, a careful study of this phenomenon is very important.

In the course of marine prospecting, a large area off the southern shore of the Apsheron Peninsula was investigated. More than 50 miles of profiling was done. The reliability of the marine seismic data is confirmed by the results of actual drilling. The continuation of the Karachukhur Puikhsk anticline

* An amplifier schematic diagram is submitted which provides for cutoff frequencies of 1,000, 100, 75, and 50 c.p.s., by means of taps on the filter choke.

† A record shot at a depth of 33 feet with a charge of about 2 lbs. shot with and without the low-pass filter is reproduced.

has been followed by seismic methods deep into the sea and a new drilling prospect has been outlined.

It is proposed to conduct a marine seismic survey along a broad strip of the Caspian Sea adjacent to the petroliferous plateaus of eastern Azerbaidzhan.

The requirements for successful marine operation are:

1) A specially equipped and very fast boat, capable of withstanding storms, and furnished with all necessary items for its crew.

2) A highly developed seismic apparatus, including marine seismometers, a set of amplifiers with sufficient flexibility in regard to frequency selectivity, and a multi-element galvanometer.

3) Auxiliary equipment of high quality, such as substantial connecting cables guaranteeing operation in sea water without appreciable electric leakage, short wave radio communication for contact with the shotpoints, etc.

Additional theoretical and laboratory research is required for the solution of some of the problems inherent in this new type of seismic exploration, but if sufficient attention is given these problems, the method should prove to be a powerful exploratory tool for the geological investigation of regions occupied by the sea.

A. J. HERMONT

Testing the Application of Air Explosions in Seismic Reflection Exploration, by A. A. Tsvetaev. *Applied Geophysics*, No. 1 (1945). Pp. 82–87. (Organ of Federal United Geophysical Trust; Scientific Research Institution of Applied Geophysics; People's Commissariat of Petroleum, U.S.S.R.)

The use of buried charges in seismic exploration usually involves the drilling of shot holes with heavy automotive equipment; moreover, the practice requires that the cheaper grades of explosives be waterproofed. Cases are on record where exploration had to be abandoned because the shotpoints were inaccessible to the heavy drilling rigs. For these reasons other methods of excitation of elastic waves have been sought. Tests in which the explosion occurred in the air have been made previously, but they were made on a small scale and in regions with unfavorable seismo-geological conditions. Their outcome, accordingly, did not produce positive results.

Upon the suggestion of the author, tests were made in the spring of 1942 in connection with salt dome exploration in the Kazak Republic. The anticipated depths of the objective ranged from 3,000 feet to 4,000 feet. The average velocity of propagation of elastic waves to these depths is about 8,000 ft/sec. Thus reflections from horizons under study should arrive at times not greater than one second. This upper time limit dictates a lower limit for the distance between the shotpoint and the seismometer nearest to it. The distance must be such that the reflections may be recorded prior to the arrival of the air waves, the latter generally obliterating the reflection on the record. In the case of work along the southern part of the River Emba, a distance of 1,150 feet was chosen.

It was found that for optimum results the charge should be suspended at a height of 5 to 7 feet above the surface of the ground, and that the average charge should be 15 to 20 times larger than the corresponding charge for conventional shot-hole shooting.

The records obtained from air shots do not differ in any significant way from those obtained from charges buried at the same location. However, a comparison of times of first arrivals as well as of reflections brought out the fact that all times for air shots are about 0.03–0.04 second larger than for buried charges. This is due of course to the increased length of travel path and in nowise complicates the process of interpretation. To ensure adequate speed of operation, the following technique was used. The spread is made equal in length to the minimum shooting distance (1,150 feet), and shots are fired into the spread from both directions along the line of the section. Associated shotpoints are therefore 3,450 feet apart. The shotpoint-spread arrangement is then advanced 1,150 feet along the section line; adjacent shotpoints are hence 1,150 feet apart, and subsurface coverage is continuous. Since shooting conditions in the air are quite uniform, the correlatability of the reflections is improved and accurate velocity determinations can be made from surface observations.

The exploration work on the domes of southern Emba permitted the use of air shots over a great variety of surfaces (rocky soil, sands, clay saturated by salt water, grassy fields). In all cases satisfac-

tory seismograms of the same general character were obtained. Part of one profile was repeated by means of the conventional shothole technique: the final cross sections differed only irrelevantly. A total of about 13 miles of profile was explored by means of air shots and the results were quite satisfactory. The seismic evidence is corroborated by the geology of the region.

The amplifiers had a considerable reserve of gain, but were otherwise normal. From the above description it becomes clear that the adaptation of air shots simplifies exploration; the absence of shotholes leads to a reduction in automotive equipment and in the size of the crew, all of which contributes to make the reflection method more flexible. The productivity of the recording apparatus is sharply increased and the method is better adapted to winter operations. And, in spite of the considerably increased consumption of explosives, operating costs are reduced.

In 1943, tests were conducted in the western part of the Turkmen Republic. Here the minimum distance between shotpoint and nearest seismometer was increased to 2,000 feet in order to obtain a maximum exploration depth of 6,500 feet. The height of the charge above the ground was reduced to 1.5 feet. Incidentally, this terrain is covered with quicksands which are impassable for automotive equipment. These tests, too, showed the practical applicability and the economic effectiveness of air shots in reflection seismology.

From the above it would seem highly desirable to try out this technique for a variety of geologic conditions. It will then be necessary to conduct special experimental work in those regions and to utilize up-to-date knowledge of explosives to obtain more intensive elastic impulses.

A. J. HERMONT

PUBLICATIONS RECEIVED

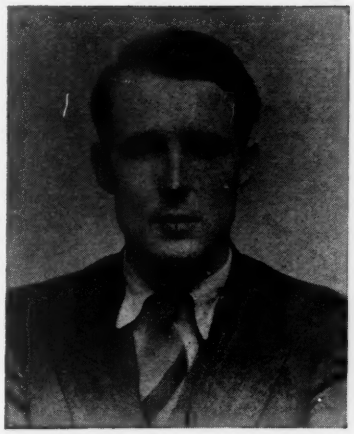
American Journal of Science, Vol. 246, No. 4 (April) 1948, No. 5 (May) 1948.
Annales de Geophysique, Tome 3, Annes 1947 (Decembre 1947).
Bokrtechnicker-Zeitung, 63 Jahrgang, Heft 5 (March 1947), Heft 4 (April 1947), Heft 9 (1947), Heft 11/12 (1947).
Bulletin of the American Association of Petroleum Geologists, Vol. 32, No. 4 (April 1948), No. 5 (May 1948), No. 6 (June 1948).
Bulletin of the Seismological Society of America, Vol. 38, No. 1 (January 1948).
Die Osterreickisch Amerikanische, 2 Jahrgang, Nr. 8 (December 1947).
Economic Geology, Vol. XLIII, No. 2 (March-April 1948), No. 3 (May 1948).
Institute of Petroleum Review, Vol. 2, No. 14 (February 1948), No. 15 (March 1948).
Journal of Applied Physics, Vol. 19, No. 3 (March 1948), No. 4 (April 1948), No. 5 (May 1948).
Journal of the Institute of Petroleum, Vol. 24, No. 290 (February 1948), No. 291 (March 1948), No. 292 (April 1948).
Nafta, Rok. IV, Nr. 3 (March 1948), Nr. 4 (April 1948).
Proceedings of the Cambridge Philosophical Society, Vol. 44, Part 2 (April 1948).
Publicaciones del Instituto de Fisiografia y Geologia, 1947.
Quarterly of Colorado School of Mines, Review of Petroleum Geology, Vol. 38, No. 3 (July 1943), Vol. 39, No. 2 (April 1944), Vol. 40, No. 2 (April 1945), Vol. 41, No. 3 (July 1946), Vol. 42, No. 3 (July 1947).
The Quarterly Journal of the Geological Society of London, Vol. CIII, Part 3 (January 1948), Part 4, (May 1948).
Report of the Executive Committee, International Council of Scientific Unions (July 1947).
The Review of Scientific Instruments, Vol. 19, No. 3 (March 1948), No. 4 (April 1948).
Terrestrial Magnetism and Atmospheric Electricity, Vol. 53, No. 1 (March 1948).
World Petroleum, Vol. 19, No. 4 (April 1948), No. 5 (May 1948).

The publications listed above have been placed in the Exchange Depository of the Society at the University of Tulsa Library. They are available to Members of the Society, and may be borrowed upon request. Address all inquiries to the Business Manager, Box 1614, Tulsa 1, Oklahoma.

CONTRIBUTORS

ERIC H. BOISSONNAS studied at the University of Paris where he received the degree of Bachelor of Philosophy in 1930, Bachelor of Mathematics in 1931, and Master's in geology, mathematics, and physics in 1938. In 1938 he joined the Societe de Prospection Electrique (Schlumberger) in Paris as engineer and branch manager in France, Rumania, Greece and Turkey. In 1941 Mr. Boissonnas was put in charge of all surface exploration work of the Compagnie Generale de Geophysique (Schlumberger) in Southern France. In July of 1946, he came to the United States and was affiliated with the Schlumberger organization in South America, and at the same time organized Geolectric Exploration Company, Inc., in Houston, Texas of which he is president, and for which he did developmental work on the use of natural earth currents.

Mr. Boissonnas is a member of the American Institute of Mining Engineers, American Association Petroleum Geologists, and the American Geophysical Union.



ERIC H. BOISSONNAS

ISIDORE ZIETZ

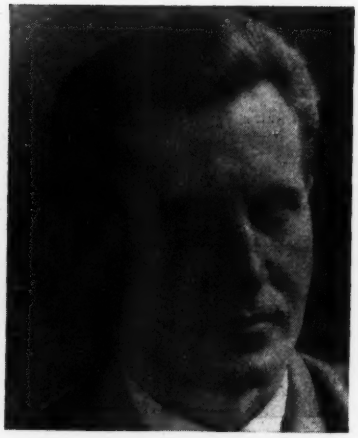
ISIDORE ZIETZ graduated with a B.S. in mathematics from the College of the City of New York in 1939. One year later he received his master's degree from the same institution. In December 1941, he accepted a field job with the U. S. Geological Survey as a topographic engineer, transferring to the Washington D. C. office in 1942 as a geodetic computer. From 1944 to 1946 he was with the U. S. Army, 30th Engineers Topographic Battalion doing geodetic and topographic work. Upon discharge he returned to the Geological Survey as a geodetic engineer. In December 1946, he transferred to the Section of Geophysics, Geologic Branch, U.S.G.S. as a theoretical geophysicist where he has been employed to the present time. For the past two years he has been a graduate student in the Department of Physics as well as instructor of mathematics at the Catholic University of America.

ROLAND G. HENDERSON

ROLAND G. HENDERSON received the bachelor's degree with majors in mathematics and physics at the Milwaukee Teachers College in 1935, where he was awarded membership in the national honor fraternity, Kappa Delta Pi. He obtained his M.S. in mathematics at Atlanta University in 1939. From 1939 to 1941 he pursued graduate studies in mathematics and physics, receiving a Julius Rosenwald Fellowship award in 1940.

He was employed by the Topographic Branch of the U. S. Geological Survey as a geodetic computer from 1942 to 1946, and as a geodetic engineer 1946 to 1947. In 1947 he transferred to the Section of Geophysics of the Survey, where he is engaged in geophysical research.

LÁSZLÓ EGYED obtained his Ph.D. degree in mathematics in 1938 at the University of Science, Budapest, Hungary. Afterwards, he was assistant to the Professor of Mathematics at the same university until 1940 when he was engaged by the Maort (Standard Oil Co., Inc., N. J.). During his time with Maort, Dr. Egyed published several papers on mathematics and geophysics and was reviewer for the *Zentralblatt für Mathematik und ihre Grenzgebiete*. In 1946, Dr. Egyed became lecturer of applied geophysics, and in 1947, Associate Professor at the University of Science, Budapest.



LÁSZLÓ EGYED

R. MAURICE TRIPP received the degree of Geological Engineer from the Colorado School of Mines in 1939 and returned to the Geotechnical Corporation to resume work in various phases of seismic operations which he had begun in 1936 and 1937. Subsequently, he received the degree Master of Geophysical Engineering from the Colorado School of Mines, and after another interval of employment, received the Doctor of Science in geology at M.I.T.

From 1944 to 1946, he was assistant to the president of the Geotechnical Corporation, and director of the research program. He also served as Senior Scientist for the Bureau of Ships in planning and executing the program of seismic measurements at Bikini. Since 1947 he has been engaged in research and consulting in the field of geochemistry and petroleum geology.

Mr. Tripp is a member of the American Association of Petroleum Geologists, Society of Exploration Geophysicists, American Geophysical Union, Seismological Society of America, American Institute of Mining and Metallurgical Engineers, American Association for the Advancement of Science, Sigma Xi, Tau Beta Pi, and Sigma Gamma Epsilon.

R. MAURICE TRIPP

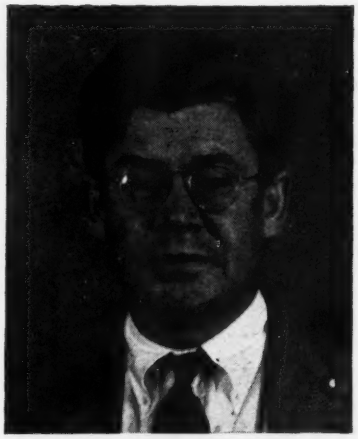
FRANK PRESS

FRANK PRESS received his B.S. degree in physics from the City College of New York in 1944, and his M.S. from Columbia University in 1946. He was Teaching Assistant in physics, 1945 to 1946, and University Fellow, 1946 to 1947 at Columbia where he is now completing his requirements for the Ph.D. degree, specializing in geophysics. Since 1946, he has been a member of the scientific staff, Columbia University Division of Government Aided Research, working on theoretical and field problems of elastic wave propagation.

J. LAMAR WORZEL

J. LAMAR WORZEL received his B.A. degree in engineering physics from Lehigh University in 1940. From 1940 to 1946, he worked at contracts, on problems of underwater sound transmission and submarine photography. In September, 1946, he entered the graduate school of Columbia University, Department of Geology, and received his M.A. degree, specializing in geophysics, in June, 1947. He is at present continuing his graduate work at Columbia, while serving as Geodesist on a program of measurements of gravity at sea, under a contract between Columbia University and the Office of Naval Research.

Mr. Worzel is a member of the Sigma Xi Society, the American Physical Society, the New York Academy of Sciences, the American Geophysical Union, and the Society of Exploration Geophysicists.



MAURICE EWING

MAURICE EWING received his B.A. (1926), M.A. (1927), and Ph.D. (1931) degrees from the Rice Institute, Houston, Texas. He was on the faculty of Lehigh University from 1930 to 1944, and is now Professor of Geology at Columbia University, and Research Associate of the Woods Hole Oceanographic Institution. His research, the geophysical investigation of the structure of continents and ocean basins, includes extensive measurements of gravity at sea, seismic surveys of the Atlantic continental shelf and ocean basin, wartime work on underwater sound transmission, underwater photography, oceanographic instrumentation, and exploration of the Mid-Atlantic Ridge.

GORDON ATWATER

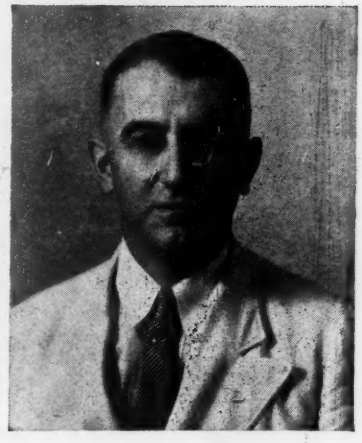
GORDON ATWATER received his degree of B.A. in economics at the University of Iowa in 1928 and his degree of M.S. in geology in 1929 from the same university. He received his Ph.D. in geology at the University of Wisconsin in 1935 after graduate work both at that school and at Columbia University.

He started work in the Gulf Coast region in 1935 with Amerada Petroleum Corporation in Houston, later transferring to the Skelly Oil Company in Houston. In 1938 he moved to New Orleans as Chief Geologist and head of the Land Department for William Helis, and late in 1946 opened offices as consulting geologist in New Orleans.

Mr. Atwater is a member of Sigma Xi, the Society of Exploration Geophysicists, and the American Association of Petroleum Geologists. He helped organize the New Orleans Geological Society in which he has served as president.

EUGENE G. LEONARDON received the degree of Bachelor of Science from the Lycee St. Louis, Paris, France in 1907 and graduated from Ecole Polytechnique in 1912. In 1914, he received his Master's degree in Law from the University of Paris. From 1919 to 1925 he was with the Societe de Prospection Electrique as engineer, district manager, and general manager, also doing field work in France, North Africa, Sarre, and Rumania. From 1926 to 1931, he was general manager for the same company in North America with activities both in the U. S. and Canada, and from 1931 to 1934 he was general manager in Paris, and concurrently assistant manager of the Compagnie Generale de Geophysique, also in Paris. In 1934, he was made vice president of Schlumberger Well Surveying Corporation in Houston and in 1939 was made president. From 1946 to the present time, he has been director of Schlumberger.

Mr. Leonardon is a member of the American Institute of Mining Engineers, American Association of Petroleum Geologists, Society of Exploration Geophysicsts, American Petroleum Institute, American Geophysical Union, and the American Society of Electrical Engineers.



EUGENE G. LEONARDON

PAUL M. HANAHEN

PAUL M. HANAHEN, Bureau of Mines Safety Instructor, attended Carnegie Institute of Technology, taking the two-year course in Coal Mine Engineering. Following that, he worked for approximately 25 years in the anthracite coal mines during which time he made a study of the use of explosives in mines. Since 1935 he has been a member of the staff of the Health and Safety Division of the U. S. Bureau of Mines for whom he has been author and co-author of various publications on the safe use and handling of explosives.

During World War II, Mr. Hanahen was Explosives Investigator and devoted much of his time to the problems of handling, storing, and transporting of explosives by geophysical parties. He has also designed equipment for demonstrating the safe handling of geophysical explosives and has taught accident prevention courses to geophysical crews.

The photograph and biography of Cecil H. Green was published in GEOPHYSICS, Vol. XI, No. 1, page 113.

OFFICERS FOR THE YEAR ENDING MARCH, 1949

Left to right: E. V. McCollum, Secretary-Treasurer; Cecil H. Green, Past President; L. L. Nettleton, President; M. King Hubbert, Editor; Andrew Gilmour, Vice-President.

THE SOCIETY ROUND TABLE

PAPERS PRESENTED OR READ BY TITLE AT THE TECHNICAL SESSIONS OF THE EIGHTEENTH ANNUAL MEETING

MONDAY MORNING, APRIL 26

TECHNICAL SESSION I

Silver Glade, Cosmopolitan Hotel

Seismic Surveying Techniques on Land and Sea

10:00 A.M. to 12 NOON

(See also concurrent Session II, Room D, Cosmopolitan Hotel)

Presiding: M. KING HUBBERT AND W. J. OSTERHOUDT

1. 10:00 J. WILLIS HUGHES, Jackson, Mississippi.

Seismic Exploration in Mississippi.

The paper presents a concise history of seismic work in Mississippi, discusses the problems encountered, reviews the results obtained, and submits the writer's recommendations for more effective exploration.

2. 10:25 MARTIN C. KELSEY, Rayflex Exploration Co., Dallas, Texas.

Studies in Fault Detection with the Reflection Seismograph.

Faulting has long been recognized as an important factor in the formation of traps for the accumulation of oil and gas. A discussion is presented of some of the problems connected with fault interpretation, together with suggestions as to methods which may be employed to assist in the solution. Field data and final fault interpretation of a peculiar problem are herein illustrated.

3. 10:50 P. M. HANAHEN, Health and Safety Div., U. S. Bureau of Mines, Dallas, Texas.

Explosives Accidents on Geophysical Crews.

The need of a standard set of safety rules is emphasized. There are indications that seismic personnel has become somewhat careless since the removal of some of the war-time regulations. The Texas City disaster has called attention to hazards of handling explosives on docks and boats and to smoking regulations.

Dangers associated with the use of liquefied petroleum gases on boats and methods of avoiding them are pointed out. Studies of premature ignition from electric current generated by aluminum loading lines and by static electricity are reviewed.

4. 11:10 R. L. PALMER, McCollum Exploration Co., Houston, Texas.

Field Techniques in Marine Seismic Exploration.

This paper presents a brief history of marine seismic exploration accomplished in submerged areas prior to 1944. For the most part this exploration covered inland or protected waters, and only in a few instances were offshore explorations undertaken. The increase in the demand for oil and the diminishing returns from land exploration gave the impetus required to start marine research and exploration in the Gulf of Mexico and other large areas of submerged land.

This paper also gives a brief history of the refraction method as a means of reconnaissance ex-

ploration, with its merits and limitations. There are several illustrations showing line layouts and buoys adaptable to this type of exploration.

The paper then follows with a detailed discussion, accompanied by numerous illustrations giving the history of reflection marine techniques and equipment developed since 1944. This discussion deals primarily with five phases of field operation, namely surveying, sizes and types of boats most suitable for work, placing of shots in water, line layouts for reconnaissance and detailed surveys, and methods of placing geophones in water.

The paper ends with an illustration showing the approximate acreage already leased in the Gulf of Mexico from Brownsville, Texas, to Mobile, Alabama.

5. 11:35 THOMAS L. ALLEN, Petty Geophysical Co., San Antonio, Texas.

Problems in Marine Seismic Exploration.

Seismic exploration conducted in coastal waters of the Gulf of Mexico off the states of Mississippi, Louisiana, and Texas has met several problems not ordinarily encountered in comparable work on land. The matter of public relations is probably the most unusual. Protests of commercial fishermen and, to a limited extent, of sports fishermen have had to be considered.

The problem of surveying, particularly when the work is several miles offshore, has been partially solved by the adaptation of electronic instruments used during the war for aerial navigation or air-raid warning devices.

Conversion of seismic instruments, which were developed for use on land or shallow inland waters, into satisfactory marine equipment is also a problem that has not been completely solved.

PAPERS READ BY TITLE

6. W. B. AGOCS, Lehigh University, Bethlehem, Pennsylvania.

Sea Bottom Slope Determination from Water Sound Arrivals.

Previously it was shown how the time break could be determined on deep-sea seismic records from the water sound arrivals. An extension of the previous problem has been made, for the more general case of a sloping sea bottom. By successive approximations, it is found that from a ratio of the difference of direct water wave arrival and the first reflection from the surface of the sea, and the difference in time of the second and first reflection times, and the ratio of difference in time of arrival of the second and first reflections to the difference in time of arrival of the third and second reflections from the surface of the sea, the depth of shot below the surface of the sea, shot-detector distance and the direction and magnitude of the sea bottom slope may be determined. The converse of the method could be used to determine sea bottom slopes in hydrographic surveys.

7. J. W. HORN, Garrett Exploration Co., Dallas, Texas.

Use of the Light Airplane in Geophysics.

A light airplane has been found to have several uses in geophysical work. It has been found to be both effective and economical for scouting prospective areas and areas under survey. In some areas supervision can be greatly expedited. It has been found very useful for transportation of personnel, equipment and supplies where time is the important factor. The plane can be used to maintain close contact between the field office and central office with an appreciable saving of time. It has been used in special emergencies and in one case perhaps saved a man's life. The most useful plane is one with a top cruising speed of approximately 100 miles per hour, a minimum safe cruising speed of about 65 miles per hour, and a landing speed of about 45 miles per hour. Total cost of operation of such a plane, with moderate flying time, has been found to approximate the cost of the same transportation by automobile.

MONDAY MORNING, APRIL 26

TECHNICAL SESSION II

Room D, Cosmopolitan Hotel

10:00 A.M. to 12 NOON

Aeromagnetic Exploration; Magnetic Interpretation

(See also concurrent Session I, Silver Glade, Cosmopolitan Hotel)

Presiding: E. A. ECKHARDT AND ANDREW GILMOUR

8. 10:00 John BEMROSE, Shell Oil Co., J. C. HEGGBLOM, Gulf Research & Development Co., T. C. HOLT, Superior Oil Co., T. C. RICHARDS, Anglo-Iranian Oil Co., R. J. WATSON, Standard Oil Company of New Jersey.

The Bahamas Airborne Magnetometer Survey.

This paper presents some of the background prior to the actual survey, the functioning of the participants "Technical Committee" and its relationship to the contractors. A brief outline is also presented covering the various technical phases of the operation together with some of the inherent hazards of the area and how they were handled, and concluding with a summary of recommended changes in equipment and procedure for any future project of the same type.

9. 10:25 HOMER JENSEN, Aero Service Corp., Philadelphia, Pennsylvania.

Some Technical Aspects of Bahamas Airborne Magnetometer Survey.

The Bahamas airborne magnetometer survey, discussed last year as a project about to begin, was completed in November. As a large scale, coordinated application of the airborne magnetometer, Shoran, and other new electronic devices, this survey illustrates most of the problems and techniques involved in the practical application of these devices. New techniques of magnetic control were developed to take advantage of the surprisingly low diurnal variation encountered in the area. It was demonstrated that the quality of magnetic information derived from an aerial survey of basement structures is superior to that of the best ground surveys and that Shoran provides a practical system for establishing low-order geodetic position as well as accurate local flight guidance. An analysis of production and cost factors in aerial surveying indicates that airborne magnetometer surveys have certain optimum operational levels of intensity, depending on such factors as base facilities, area involved, and weather.

10. 10:50 ROLAND F. BEERS, Geotechnical Service Corporation, Dallas, Texas.

Some Problems of Magnetometer Surveys.

The development of the continuously recording mobile magnetometer presents new factors in geophysical operations. The characteristics of these new instruments are described, together with features which adapt themselves to new exploration planning. It is observed that new areas of application have been uncovered by virtue of the economies of mobile operations. Comparisons are made between airborne and surface operations.

11. 11:15 ROLAND G. HENDERSON AND ISIDORE ZIETZ, U. S. Geological Survey.

Analysis of Total Magnetic Intensity Anomalies Produced by Point and Line Sources.

The component of total magnetic intensity in the direction of the earth's total field, the quantity measured by the airborne magnetometer, is studied in relation to point-pole and line-of-poles sources. Theoretical profiles are examined for maxima and minima, and it is established that the depth is a linear function of the half-maximum abscissa. A family of curves is presented by means of which factors can be obtained for use in estimating depths. The well-known factors used with vertical intensity profiles are included as a special case. An example is given in which the factors are used in analyzing a theoretical anomaly.[1]

[1] Published by permission of the Director, U. S. Geological Survey.

12. 11:40 KENNETH L. COOK, Section of Geophysics, U. S. Geological Survey.

Some Aspects of the Quantitative Interpretation of Magnetic Anomalies Over Vertical and Inclined Veins. Part I.

By using ordinary induction methods of analysis, Haalck, Heiland, and others have developed formulas which express the magnetic anomalies over vertical and inclined veins of tabular shape as functions of the susceptibility, dimensions, and disposition of the vein and of the strength and direction of the earth's field. On the basis of these fundamental formulas, other formulas for the vertical component of the magnetic field are derived for such veins in intermediate northern magnetic latitudes. Special emphasis is given to the orientation of the veins relative to the magnetic north direction. Several families of magnetic response curves for veins with different strikes and dips, which have been computed in part by a graphic method, are given. All theoretical curves for veins striking magnetic north are plotted in terms of a parametric unit so that, once plotted, they can be used universally in any district, provided a proper multiplying factor is chosen for the observed curve. A graphic method of choosing the proper multiplying factor is shown. The importance of the transverse horizontal magnetization effect under certain conditions of orientation is demonstrated. It is shown mathematically that small anomalies are to be expected for veins striking east and dipping south at an angle that is equal to, or approximately equal to, the component of the angle of magnetic inclination.

13. D. C. SKEELS, Standard Oil Co. of New Jersey, New York, New York, and R. J. WATSON, Standard Oil Co. (Bahamas) Ltd.

Derivation of Magnetic and Gravitational Quantities by Surface Integration.

(Given in Technical Session IV.)

MONDAY AFTERNOON, APRIL 26

TECHNICAL SESSION III

Silver Glade, Cosmopolitan Hotel

2:00 P.M. to 5:00 P.M.

Seismo-Acoustic Well Logging; Seismic Well Velocities; Seismic Correlation and Interpretation

(See also concurrent Session IV, Room D, Cosmopolitan Hotel)

Presiding: T. A. MANHART AND A. E. MCKAY

14. 2:00 C. H. KEAN AND F. N. TULLOS, Humble Oil & Refining Company, Houston, Texas.

Acoustic Impedance Well Logging.

Several years ago, the senior author conceived the idea of placing a cylindrical sound source in a bore hole and obtaining an acoustic impedance log. There were mathematical reasons to believe that a "free-free" tube driven in its longitudinal mode would be suitable. Such a device was constructed from magnetostrictive material (nickel) and built in a way that made the system self-driven. An "automatic volume control" indicated the amplitude of the tube when a fixed driving current is applied. Highly reproducible logs were obtained on a large number of core holes, and very good correlation was obtained from hole to hole. Slides are given indicating the construction, the operation, and the results.

15. 2:25 ALEXANDER WOLF, Houston, Texas.

Acoustic Well Sounding.

The principle of the acoustic determination of fluid level in a producing well can be traced back to an idea patented 50 years ago. The paper outlines the development of the method, the instruments now available, and the purpose of acoustic well sounding.

16. 2:50 L. W. GARDNER, Gulf Research & Development Company, Pittsburgh, Pennsylvania.

Seismograph Determination of Salt Dome Boundary Using Well Detector Deep on Dome Flank.

A method is given for determining the boundary of a salt dome, based upon first arrival time measurements of seismic waves from ordinary shotpoints distributed around the dome and received by a well detector within a deep hole flanking the dome and penetrating it at depth. This case is important, first because flank deep holes become available as a by-product of drilling programs, and second because a flank location permits the acquisition of good information on the velocity distribution in the sedimentary section surrounding the dome, which information is essential to the success of the method. The three-dimensional problem of locating the dome boundary, taking account of radial and vertical changes of velocity within the surrounding sedimentary section, is solved by the determination of vertical and horizontal cross sections of "aplanatic surfaces" as set forth.

17. 3:15 WALTER J. OSTERHOUDT, Gulf Research & Development Company, Houston, Texas.

The Use of Electric Logging Equipment in Seismic Exploration.

In a Texas Panhandle area located north of Pampa, Texas, in Gray and Roberts Counties, seismograph experiments disclosed a slow velocity weathered zone, or zones, about 350 feet thick. Records from shots placed above the V_1, V_2 boundary were generally worthless. The quality of the reflection records approached an optimum if shots were detonated at critical positions below the V_1, V_2 boundary but multiple shooting ruined the holes. A small Guyod electric logger was employed to map the V_1, V_2 boundary and to predict the more favorable shooting depths. The resistivity curves on the electric logs showed a strong discontinuity at the base of the V_1 zone which correlated with seismograph measurements and calculated data from up-hole times and plats of V_2 arrivals versus shot detector distances. The electric logs were used to determine the depths to set casing, to guide the seismograph operator in the selection of favorable shothole depths, and finally by the geophysicists to check weathered zone corrections. The use of a portable electric logging equipment is recommended as an aid to seismic exploration in certain areas.

18. 3:40 ROBT. J. WELLS, Richfield Oil Corporation, and ROBERT DYK, General Petroleum Corporation, Bakersfield, California.

Well Velocity Shooting in California.

Experience in shooting wells for velocity in California is discussed under the following headings: Number and distribution of wells shot; operation of the California well velocity surveying group; average cost per well per member of the group; uses to which the velocity data are put; common difficulties encountered in shooting wells; sources of error; methods employed in interpretation and in shooting to minimize error; possible future trends.

19. 4:05 A symposium containing papers by JOHN SLOAT et al. Summarized by CURTIS H. JOHNSON, General Petroleum Corporation, Los Angeles, California.

Correlation in California.

The meaning and nature of seismic correlation is discussed and practical illustrations of the difficulties and successes encountered in employing character and time-tie correlation in California are shown. The relation between seismic correlations, electric logs, and lithology is discussed in general and in the light of specific examples, and possible uses of seismic character to outline stratigraphic traps and lateral changes of porosity and permeability are briefly considered.

20. 4:30 H. M. THRALLS, Seismograph Service Corporation, Tulsa, Oklahoma.

Seismic Interpretation Problems and Proposed Solutions by Joint Research.

Interpretation problems are occasionally encountered which defy solution by accepted interpretation procedures. Examples of such problems are shown.

The opinion is advanced that the industry as a whole is lacking the detailed information regarding

average velocities from the surface, interval velocities between key horizons, and proven correlations between seismic events and formation tops; that the possession of such detailed information in one or more specific areas is a starting point for interpretational research which should be valuable to the industry as a whole.

Other general problems to which solutions could be approached by joint research are mentioned.

A procedure for joint research is outlined and the existing organizations which might sponsor the research are named.

PAPERS READ BY TITLE

21. H. J. McCready, Seismograph Service Corporation, Tulsa, Oklahoma.

Relevant Signficant Figures in Seismic Interpretation.

The principle of relevant significant figures is introduced and its role in seismic interpretation is discussed. The importance of the principle is stressed by examples. It is indicated that recourse should be made to this principle if fallacious inferences concerning velocity, depth, and dip data are to be avoided.

22. Roland F. Beers and T. R. Shugart, Geotechnical Service Corporation, Dallas, Texas.

Seismic Velocities at Bikini.

Under contract with ONR at Bikini Atoll average vertical velocities were measured in a bore hole to depths of 1,800 feet. The measurements are of value in confirming many of the seismic results previously obtained at Bikini. They are also of value in the interpretation of related problems of sedimentology and seismology. Good agreement was observed between seismic velocities and geologic data gathered in drilling.

23. E. J. Stulken, Geophysical Service, Inc., Dallas, Texas.

Computation Aids for Solving Refractions.

A discussion of four cases is given:

1. Multiple-layered section of constant velocities.
2. Velocity of the type $v=v_0+Az$.
3. Velocity of the type $v=v_0\sqrt{1+Az}$.
4. Velocity of the general type $v=v_0(1+Az)^{1/n}$.

For each case mention is made of (*a*) a means of identifying the velocity function and (*b*) depth computation methods. The construction and use of new computational charts is described.

MONDAY AFTERNOON, APRIL 26

Technical Session IV

Room D, Cosmopolitan Hotel

2:00 P.M. to 5:00 P.M.

Electrical and Gravimetric Exploration

(See also concurrent Session III, Silver Glade, Cosmopolitan Hotel)

Presiding: Cecil H. Green and E. V. McCollum

24. 2:00 Eric Boissonnas and E. G. Leonardon, Schlumberger Well Surveying Corporation, Houston, Texas.

Survey of the Haynesville Salt Dome, Texas, by Telluric Currents.

The fact that natural currents flow through the ground has been known for quite a long time. Some of these currents are local in character; some involve the whole of the earth's surface. These latter currents are called telluric currents. Their behavior and properties are outlined in general, and their usefulness for the practical purpose of geophysical exploration is discussed at length. In conclu-

sion, an example of actual survey by telluric currents on the Haynesville salt dome (Texas) is given, which illustrates the quality of the results which can be obtained in similar cases.

25. 2:25 WM. BRADLEY LEWIS, The Elflex Company, Houston, Texas.
Electric Surveys of Salt Domes.

Surveys were made of the Long Point and Brookshire (San Felipe) domes using the Elflex method. The anomalies mapped showed excellent agreement with known subsurface geology.

26. 2:50 H. M. EVJEN, Elflex Company, Ruidoso, New Mexico.
Theory of Low-Frequency Electro-Magnetic Fields.

Based directly on Maxwell's field equations, the extremely low end of the frequency spectrum may be reduced in first approximation to simple potential theory. The approximation theory is borne out by some field experiments, the results of which are presented. Agreement with the theory, however, requires that the ground have a very large effective dielectric constant. This conclusion is supported by previous observations by a number of independent observers. Thus, the relaxation time has been found to be extremely great in samples of mud as well as in observations directly on the ground, and the sign of an electric anomaly over a relative insulator, such as crystalline salt or gas and oil, invariably has been found to be negative. Both of these observations can be explained in terms of a very great dielectric constant. The value yielded by the present experimental work is of the order of 10^{10}.

27. 3:15 KENNETH E. BURG, Geophysical Service, Inc., Dallas, Texas.
A New Light-Weight Portable Gravity Meter.

A new light-weight, portable gravity-meter of unique design is described, wherein many limitations previously encountered in such an instrument have been overcome. The basic requirements of such an instrument are outlined and the design methods used to meet these requirements are disclosed. Test and performance data are presented.

28. 3:40 W. RAYMOND GRIFFIN, Robt. H. Ray Company, Houston, Texas.
Residual Gravity in Theory and Practice.

A precise definition of residual gravity is given and in a form most suitable for numerical application. Some pains are taken to show that the residual gravity picture one obtains depends on the method used in obtaining it and that there are many ways in which this may be done. Several examples from actual work on developed oil fields are given in the form of figures and maps to bear out the above statement. Conclusions are drawn as to the relative order of sensitivity of several factors entering into the computations in determining a given residual picture. Factors considered in this paper are (1) size of unit figure, (2) kind (or shape) of unit figure, (3) density of reference net; i.e., number of reference points per unit area, and (4) sensitivity of reference points to lateral displacement on gravity map.

29. 4:05 FREDERICK ROMBERG, LaCoste & Romberg, Austin, Texas; and VIRGIL E. BARNES, Bureau of Economic Geology, University of Texas, Austin.
Correlation of Gravity Observations With the Geology of the Coal Creek Serpentine Mass, Blanco and Gillespie Counties, Texas.

Gravitational observations were made of the pre-Cambrian Coal Creek serpentine mass in Blanco and Gillespie Counties, Texas, the geology of which had been mapped previously. The observed gravitational anomalies indicate roughly the depth of the serpentine mass, below which it may possibly grade into its parent peridotite rock. Probable small-scale correlation between the gravitational map and the geology of the area is indicated.

(13) 4:30 D. C. SKEELS, Standard Oil Company of New Jersey, New York, New York, and R. J. WATSON, Standard Oil Company (Bahamas), Ltd.

Derivation of Magnetic and Gravitational Quantities by Surface Integration.

In an earlier paper by one of the authors it was pointed out that if the vertical component of a gravitational or magnetic field is known over a horizontal plane surface of sufficient extent, all other components and derivatives of the field can theoretically be calculated by surface integration of the vertical component. In this paper examples are given to show that within certain limits such calculations are not only theoretically possible but practically so. Examples are given of the calculations of curvatures from observed gradients, and of horizontal magnetic intensity from observed vertical intensity, and the calculated values are compared with those obtained by observation. Examples are also given, based on artificial data, of the calculation of plumb-line deflections from gravity, and of the calculation of magnetic anomalies at a given elevation above the earth from data obtained at the surface. The purpose of these calculations is to demonstrate the nonindependence of the various derivatives of gravitational and magnetic potential.

TUESDAY MORNING, APRIL 27

Lincoln Room, Shirley-Savoy Hotel

9:00 A.M. to 12 NOON

JOINT SESSION

Presidential and Special Addresses

TUESDAY AFTERNOON, APRIL 27

TECHNICAL SESSION V

This Program Is of Interest to All Three Societies

Silver Glade, Cosmopolitan Hotel

2:00 P.M. to 5:00 P.M.

Papers of Geophysical and Geological Interest
Presiding; W. M. RUSI, JR., and ROY L. LAY

30. 2:00 M. M. SLOTNICK, Humble Oil & Refining Company, Houston, Texas.

Recent and Current Highlights of Geophysical Exploration.

Some of the newer techniques of geophysical exploration such as the offshore work in the Gulf of Mexico, the work on the Edwards Plateau and the use of airborne magnetometer are discussed. Of the newer ideas the use of telluric currents, acoustic-impedence and well logging are mentioned as examples. Finally a brief resume of a nonstatistical nature of world-wide geophysical activity is presented.

31. 2:35 E. A. ECKHARDT, Gulf Research & Development Company, Pittsburgh, Pennsylvania.

Review of Geophysical Activity in 1947.

The volume and geographic distribution of geophysical activity will be presented in relation to the trend of such activity over recent years.

32. 2:55 W. E. PUGH, Seismograph Service Corporation, Tulsa, Oklahoma.

On-the-Job Training in Exploration Geophysics.

The lack of men trained specifically for exploration geophysics resulted in the institution of an on-the-job training program for overcoming, at least in part, the roots of the difficulty. The subject is

treated principally from the point of view of seismograph work. The development of the program from conception to inauguration is discussed briefly, along with the presentation of selected excerpts from the training material, and diagrams to illustrate its proposed (theoretical) execution. The actual operation of the training program and the difficulties encountered are analyzed, objectively and in retrospect. The paper is terminated with a brief resume of the results obtained, and conclusions.

33. 3:20 JOHN H. HODGSON, University of Toronto, Ontario, Canada. (Presented by A. A. Brant.)

A Seismic Survey of the Canadian Shield.

A series of large rockbursts, occurring at Lake Shore Mines, Kirkland Lake, Ontario, offers a source of energy for the investigation of the crustal structure underlying the Canadian Shield. In order to obtain a refraction profile, two field stations, each equipped with three-component Sprengnether seismographs, will be operated at a succession of points along a line between Kirkland Lake and Ottawa. Each point will be occupied until a burst has been recorded.

The paper outlines the peculiar advantages of rockbursts as a source of energy, and describes the instrumental and mechanical details of the project, which was instituted on July 1, 1947.

34. 3:45 J. E. HAWKINS, Seismograph Service Corporation, Tulsa, Oklahoma.

Radio Survey and Navigation Systems.

A general description is given of the various radio position locating systems. The differences are pointed out between pulse-type systems and continuous wave systems. The essential features are described of a system which has been developed to meet the requirements of the oil exploration industry.

PART I, Classification:

35. 4:10 EUGENE MCDERMOTT, Geophysical Service, Inc., Dallas, Texas.

Microstructure and Behavior of the Sediments: Part I. Classification

The sediments may be usefully described in terms of three primary kinds of atomic configurations (microstructures). Subsurface fluids are also described. This may be called a first step in the direction of understanding the anatomy and physiology of the sediments.

P. E. HAGGERTY, GALE WHITE, and EUGENE MCDERMOTT.
Geophysical Service, Inc., Dallas Texas.

Part II, *Experimental Geophysical Data.*

Some experimental geophysical data are presented bearing on the behavior of the sediments under the influence of forces of short and long time duration.

Part III, Experimental Geochemical Data.

W. R. RANSOME, E. C. REAGER, Geochemical Surveys, and EUGENE MCDERMOTT, Geophysical Service, Inc. Dallas, Texas.

Some experimental geochemical data are presented bearing on the changes that take place within the relatively more fixed basic anatomy of the sediments.

EUGENE MCDERMOTT, Geophysical Service, Inc., Dallas, Texas.

Part IV, Some Theoretical Considerations.

Some theoretical considerations are offered for the purpose of indicating connections between the observed behavior of the sediments and the basic microstructure of the sediments. On the basis of a rational frame of reference various directions of needed research are pointed out.

(Discussion after Part IV)

WEDNESDAY MORNING, APRIL 28

TECHNICAL SESSION VI

Silver Glade, Cosmopolitan Hotel

9:00 A.M. to 12 NOON

Geophysical Case Histories

(See also concurrent Session VII, Room D, Cosmopolitan Hotel)

Presiding: HENRY C. CORTES AND FRANK GOLDSTONE

36. 9:00 W. S. OLSON, Texas Petroleum Company.

Geophysical History of the Tucupita Oil Field, Venezuela.

The Tucupita oil field in the Orinoco delta was discovered as a result of a regional seismic survey for The Texas Company. There is a brief description of the area and maps are presented showing correspondence of drilling results with seismic interpretation. The oil accumulation is due to a fault which interrupts the regional monoclinal dip.

37. 9:25 HARRY M. BUCHNER, The Carter Oil Company, Shreveport, Louisiana.

Geophysical History of the Buckner Field, LaFayette and Columbia Counties, Arkansas.

The presence of a structural feature at Buckner was first indicated by a reconnaissance seismic survey of The Standard Oil Co. of Louisiana in the fall of 1936, at which time reflections from the Nacatoch (Gulf Cretaceous) were mapped. The area was resurveyed in more detail by the same company in the early part of 1937. During this survey, reflections from Glen Rose horizons and from the top of the Smackover limestone were mapped. Following this survey, the prospect was leased by The Standard Oil Co. of Louisiana and subsequently drilled to result in the discovery of the first commercial Smackover production in Arkansas Development of the western portion of the field proceeded rapidly. A detailed seismic survey was conducted in the fall of 1938 to evaluate acreage east of the eastern limits of production at that time. This work resulted in the drilling of the discovery well for the eastern portion of the field.

38. 9:50 Seismic by L. C. SPENCER, Atlantic Refining Co., Shreveport, Louisiana, Gravity by JACK W. PETERS, Magnolia Petroleum Company, Dallas, Texas.

Geophysical Case History of the Magnolia Field, Columbia County, Arkansas.

A brief history of events leading to the discovery of the Magnolia field of Columbia County, Arkansas, is given. Seismic maps of shallow and deep horizons are presented as interpreted from data obtained by the Atlantic Refining Company. These maps show this field to be located on a large anticlinal structure of salt origin. Absence of structural evidence below the Louann salt is shown, and the shift in position of the structural axis from the shallower to the deeper information is pointed out.

Gravity meter data obtained in this area by the Magnolia Petroleum Company subsequent to both the discovery of the field and the Atlantic Refining Company seismic survey are included. The pronounced minimum gravity anomaly observed at the Magnolia field is obviously the reflection of the deep salt structure which was delineated by the Atlantic Refining Company seismic survey. An analysis of measured and predicted conditions, and gravity calculations based on the seismic salt structure are also presented and support the gravity interpretation.

39. 10:15 N. R. SHADE, General Petroleum Corporation, Los Angeles, California.

Geophysical History of the Cole Creek Field Near Casper, Wyoming.

This paper, with maps, describes the seismograph and gravity surveys and results obtained over Cole Creek oil field. A map made later from data obtained by development drilling is shown for comparison. There is a good agreement between the geophysical data maps and the maps made from well

data. The geophysical field methods and the methods of presentation of the data are described and examples of seismic records and cross-sections are shown.

40. 10:40 N. R. SHADE, General Petroleum Corporation, Los Angeles, California.

Geophysical History of the Wilmington Oil Field, Los Angeles Basin, California.

This paper, with maps, describes the 1936 seismograph survey and results obtained over Wilmington Oil Field prior to the discovery of oil by drilling. A map made from data obtained by drilling in the development of the field is shown for comparison. There is very good agreement between the 1936 seismograph map and the 1946 map made from well data. The field methods and the methods of presentation of data are described, and examples of seismic records and sections are shown.

WEDNESDAY MORNING, APRIL 28

TECHNICAL SESSION VII

Room D, Cosmopolitan Hotel

9:00 A.M. to 12 NOON

Geophysical and Geochemical Prospecting in Mining

(See also concurrent Section VI, Silver Glade, Cosmopolitan Hotel)

Presiding: J. J. JAKOSKY and JOHN H. WILSON

41. 9:00 LEROY SCHARON, Washington University, St. Louis, Missouri.

Application of Geophysical Methods in the Frederickstown Lead District, Madison County, Missouri.

Magnetic and electrical measurements were carried out in two local mining areas (1) to develop techniques for locating lead ores and (2) possibly to discover new lead deposits. The lead ore occurs as replacement of dolomite where the underlying sandstone wedges out on the flanks of igneous masses. Magnetic measurements were carried out to locate buried igneous knobs and ridges. Resistivity measurements were used to map contacts of dolomite and sandstone with each other or with igneous masses and to locate fractures favorable for mineralization.

Tests over areas known from mining operations indicated reliable results. Mining and drilling results following magnetic and resistivity work over nearby untested areas confirmed (1) the inferred fractured area, (2) the location and depth of the buried igneous highs, and (3) the positions of the various geological contacts indicated by geophysical data. The measurements indicate conditions favorable for mineralization but do not give direct indications of ore.

42. 9:20 KENNETH LORIMER COOK, Section of Geophysics, U. S. Geological Survey.

Magnetic Surveys in the Iron Springs District, Iron County, Utah.

Some 62,000 magnetometer stations were made by the Division of Geophysical Exploration of the U. S. Bureau of Mines in the Iron Springs district, in an area about 5 by 22 miles. Iron ore bodies occur as replacement pods in a favorable limestone bed at the margins of igneous intrusions. The ore is a mixture of magnetite and hematite with 14 to 58 percent magnetite. Surveys were made over outcropping bodies, to determine their size, shape and ore tonnage and in geologically favorable areas to locate new ore bodies.

The survey found 45 anomalies considered as possible evidence of ore bodies, including 13 on outcropping bodies of commercial size. Core drill testing has confirmed some of the findings, both of new ore bodies and of predicted form and extent of outcropping bodies. With the aid of the magnetic results, confirmed by a single core test, a very few carefully planned additional core tests can give a large amount of information about an ore body.

43. 9:40 J. T. RANDALL, Geo-Technical Development Company, Ltd., Toronto, Ontario, Canada.

Geological Interpretations as a Result of Geophysical Explorations of a Section of the Lynn Lake Area, Manitoba, Canada.

A composite geomagnetic map of an 8,000-acre area discloses major structural conditions within a belt of pre-Cambrian rocks. Factual geologic data are scarce, and alone hint at only minor structures.

The purpose of the paper is to show the possibilities of mapping the geology in overburdened areas of the pre-Cambrian by geomagnetic and electrical methods.

44. 10:00 R. A. PETERSON, United Geophysical Company, Pasadena, California.

Use of the Seismograph in Mineral Exploration.

The usefulness of conventional seismograph equipment in mineral exploration is limited mainly to surface refraction surveys, including determinations of depth to bedrock in placer deposits, and similar applications. On a few cases reflection surveys may give "regional" structural data of value. In underground surveys in mines, the relatively limited size of ore bodies requires increased "resolving power," which may be obtained by utilizing frequencies in the range of 200–1,000 cycles per second and higher. Interpretation of data is facilitated by wave front mapping methods whereby the presence of bodies of high or low velocity rock may sometimes be detected from distortions in the shape of the initial wave front. Under favorable circumstances reflection data of value may be obtained from underground shot points. The success of seismograph surveys in mineral exploration will hinge largely on the ability of seismologists and geologists to translate seismic data into geological information.

45. 10:20 L. B. SLICHTER, University of California, Los Angeles, and S. C. SNOWDON, University of Wisconsin, Madison.

Inductive Method of Prospecting for Conducting Ores.

This paper consists of two parts: (1) An instrumental analysis, in which rational design of the basic electrical components of the inductive system is discussed, from the point of view of sensitivity and efficiency; and (2) a description of initial field tests which were performed at frequencies of 200, 800, 3,200, and 12,800 cycles per second, for the purpose of studying the dependence of the response, upon frequency, and upon the geological conditions. This part of the investigation is still in its preliminary stages.*

46. 10:40 D. F. BLEIL, Naval Ordnance Laboratory, Washington, D. C.

Induced Polarization—A Method of Geophysical Prospecting.

Geophysical prospecting by the method of induced electrical polarization, as discussed in the literature, is subject to criticism. Laboratory experiments using metallic targets in a medium of quartz sand and also in salt water, have been performed to study the fundamental relations involved and to settle some of the discrepancies existing in the literature. It has been found that the polarization induced (*IP*) is a linear function of the potential gradient applied, requiring no threshold potential, but showing a saturation potential which is slightly larger than a volt. There is also a saturation effect with time which is a function of the resistivity of the surrounding medium. The decay curves (*IP* vs. time) obtained are not exponential in character and endure for a time which is too long for the ordinary transient phenomenon. No polarization has been observed for clean sand or fresh or salt water, but a polarization potential is always measured in the earth in regions which are considered to be free, in a commercial sense, of electrically conducting minerals. Theoretical explanation of the earth's polarization is given in terms of the results of the laboratory experiments. The field apparatus is described and the results of the field survey work are interpreted in terms of the laboratory results.

* This work was supported by funds from the Geological Society of America, through a special Committee for Research in Geophysical Prospecting consisting of C. H. Behre (chairman), W. O. Hotchkiss, M. M. Leighton, and L. B. Slichter.

47. 11:00 V. P. SOKOLOFF, U. S. Geological Survey, Denver, Colorado.

Chemical Prospecting for Ore.

The study of unusual concentrations of metals in soils, plants and waters is a relatively new development in ore prospecting. Such concentrations often form an interrelated series of anomalies, termed a "dispersion halo" which may be correlated with geologic and geophysical data. Types of "dispersion halos" include mechanical dispersion, buried, saline complex. Elements of present interest are lead, zinc and copper which disperse differently in different climates and environments. For instance, zinc to a far greater extent than copper can be found in waters (the dispersion train) miles away from its source.

48. 11:20 H. V. WARREN and C. H. HOWATSON, University of British Columbia, Vancouver.

Biogeochemical Prospecting for Copper and Zinc.

Agriculturists have long been interested in the minor-element content of trees and lesser plants and of the soils in which they grow. The authors have been interested in the relation of plants to ore deposits and have carried on in British Columbia a series of investigations which indicate that the zinc and copper content of some trees and lesser plants may reflect, to a striking extent, the presence of zinc and copper concentrations in the underlying soils or rock formations.

WEDNESDAY AFTERNOON, APRIL 28

TECHNICAL SESSION VIII

Silver Glade, Cosmopolitan Hotel

2:00 P.M. to 5:00 P.M.

Symposium on Geophysics in Mining

Presiding: C. A. HEILAND and L. L. NETTLETON

49. 2:05 C. A. HEILAND, Colorado School of Mines, Golden, and Heiland Research Corporation, Denver, Colorado.

Introduction: How Can Geophysics Be of Better Service to the Mining Industry?

By comparison with geophysical oil exploration, geophysical prospecting in mining is of limited scope, both areawise and dollarwise. To begin with, geologic exposures are abundant in many mining districts, making the application of geophysics unnecessary. Exploration targets in mining are usually so small by comparison with the promising area that blanket exploration becomes too costly if not impossible. The geophysicist is handicapped not only by difficult transportation but difficult topography as well, which in addition produces a direct effect on some of his readings. Geophysical data are difficult to interpret because of geologic complexities; to make matters worse, the methods most applicable in oil exploration, such as seismic and gravimetric, are frequently of limited usefulness. A geophysicist undertaking a mining project must keep these limitations well in mind. He should not recommend the application of geophysics where no better than existing geologic information can be anticipated. If possible, he should limit the size of prospecting territory by geologic reasoning and test his methods under known conditions. Above all, he should have not only sufficient geologic training, but good geologic imagination as well when analyzing his findings. He should not oversimplify his problems nor oversell his wares. On the other hand, he should feel justified in asking a fair compensation for his services because high standards of training in both physics and geology, plus a background of long experience, are required to do a good job. The mining industry can help by supplying freely, rather than withholding, all geologic data available and by assisting in the financing of industrial research aimed at the development and perfection of new methods. Organizations specializing in geophysical mine exploration are rarely in a position to do so. Many a mining geophysicist stays with his calling not because he expects great financial returns, but because he loves his job with its variety of geophysical problems and its fascinating complexity of geology. Geophysicists in mining have com-

mitted more than their share of errors with resultant disappointment on the part of industry. However with a better understanding of the industry's problems by the geophysicist, and the geophysicist's problems by the industry, there is no reason why the use of geophysics in mining cannot be extended.

50. 2:15 G. M. SCHWARTZ, Director, Minnesota Geological Survey, Minneapolis.

Some Aspects of Ore Deposits Important in Geophysical Work.

The application of geophysics to mining problems is much more difficult than is the case with the petroleum industry. The fundamental contrasts between the occurrence of petroleum and ores are outlined. Difficulties arise because of the great complexity and variation in occurrence of commercial metallic and nonmetallic minerals. These complexities are discussed and illustrations cited in terms of mineralogic, petrographic, structural, and genetic variations in ores.

One of the important problems in the application of geophysics to ore finding is determining the definite relations of ore to specific geologic features, so that the results of geophysical work can be interpreted in terms of the probable location of more ore. This is essentially a geologic problem and one not easily solved in many districts. For the successful application of geophysics and interpretation of the results, a very detailed knowledge and understanding of the geology is fundamental. Also additional geophysical methods are required, particularly those which might locate ore directly rather than indirectly through the geology as is largely the case in petroleum.

Because of the complexities involved, no one method should be considered a true test of an area but several methods should be utilized. Much more extensive and intensive application of geophysics to problems of ore-finding is demanded by the rapid depletion of present ore reserves.

51. 2:40 L. C. ARMSTRONG and D. M. DAVIDSON, the E. J. Longyear Company, Minneapolis, Minnesota.

The Practical View in Geophysical Exploration for Metallic Ores.

This is a nontechnical paper dealing with the potentialities of geophysics in the search for metallic ore bodies which do not outcrop. It emphasizes what exploration engineers are entitled both to expect as well as to demand from geophysical surveys.

Harmful misconceptions and frustrations have arisen among mining men through lack of understanding of the possibilities of the various methods, and through confusion traceable to the loose claims and looser interpretation of results on the part of some geophysical surveyors. The miner should be made to understand that geophysical methods merely measure forces, either inherent, or induced, in various rock bodies, and that high geological competence is usually needed to judge whether anomalous measurements may be correlative with ore, likely ore-bearing structures or with features totally unrelated to ore occurrences. Since they do not put any tags on ore bodies, as some have been led to believe, the capabilities and limitations of the methods need further clarification.

The biggest hurdles to overcome before geophysics can reach a fuller measure of its true potentialities in ore finding are, first, the development of techniques for mitigating or eliminating the anomalous effects of overburden; second, development of methods for detection of disseminated metallic sulphide deposits; third, perfection of techniques of investigating the rocks surrounding bore holes for appreciable distances; fourth, the improvement of techniques for geophysical prospecting underground; fifth, independent consultation before a survey is started to weigh dispassionately the chances for success, and geophysical surveys should be checked with much pains and precision by repeating traverses and readings; sixth, reduction in costs for all methods; and seventh, modification and improvement in efficiency of equipment with special attention to increasing depth range.

Finally, there is a critical need for research, both long-range, indirect, fundamental research, as well as direct research on known ore deposits which have not been disturbed too much by development or mining. This latter will be most profitably carried out if undertaken by private mining companies on their own properties and with complete cooperation with their own geological staffs.

52. 2:55 ARTHUR A. BRANT, Associate Professor of Geophysics, University of Toronto, Toronto, Ontario, Canada.

Some Limiting Factors and Problems of Mining Geophysics.

The force field methods, magnetic, electrical resistivity and equipotential, self-potential, electromagnetic, gravimetric and geothermal where the forces observed result from the action of a natural or artificial field are all limited by the decrease in anomaly according to an inverse power law with the depth of the anomalous body. Furthermore large physical property contrasts frequently occur in the surface material, making the detection and interpretation of subsurface conditions difficult.

The mining structures controlling ore deposition are small measuring the order of feet to hundreds of feet and are manifold in number. The direct detection of ore is seldom possible.

A more accurate assessing of the limitations and scope of existing methods to know the extent of their application, more rigorous mathematical interpretation procedures, development of methods for the detection of scattered sulphides, and drill hole and underground exploration techniques are suggested as worthy of study.

53. 3:15 HANS LUNDBERG, Hans Lundberg, Ltd., Toronto, Ontario, Canada.

Choice of Methods in Geophysical Exploration for Ore.

This paper discusses the methods used for two surveys for ore bodies in the Canadian pre-Cambrian shield. The results of the surveys and of the drilling are shown. The need for using more than one geophysical method and of adapting their choice to the geologic problem at hand is clearly indicated.

MINUTES

ANNUAL BUSINESS MEETING

April 26, 1948

The Annual Business Meeting of the Society of Exploration Geophysicists was held in the Silver Glade Room of the Cosmopolitan Hotel, Denver, Colorado. The meeting was called to order by President Cecil Green at 9:00 A.M., April 26, 1948.

Mr. Green expressed the appreciation of the Society to Dr. Nettleton, general program chairman, and to the local and regional committees for their splendid support and co-operation in arranging such a full program.

The minutes of the Annual Meeting held in the Biltmore Hotel, Los Angeles, California, March 25, 1947, were read by the Secretary and approved as read.

Dr. L. L. Nettleton, Vice-President of the Society and chairman of the General Program Committee, gave his report to the Society. The fact that fifty technical papers were being presented and a mining symposium being held at this meeting was reported. Also, the progress being made on the cumulative index was given. A copy of the Vice-President's report is attached and shown as Exhibit A. The report was accepted .

The report by the editor of the Society, M. King Hubbert, was given. He pointed out that four issues of GEOPHYSICS had been edited during the year from April 1947 to April 1948. The total printed pages of these issues amounted to 514. During the year, the editor and business manager worked out a new system for the division of labor between the editor and the business manager which led to a far more efficient use of both parties' time. Also, scheduling of publication became much easier and was improved. Progress in the Patent Section and in the Reviews Committee was also reported. (For complete report see Exhibit B.) The report was accepted.

The business manager, Mr. Colin Campbell, reviewed the progress made by the Society during the past year and the business activities of his office. He described the expansion of the business office facilities as the result of greatly increased membership and activities. The report was accepted.

The Treasurer, Mr. T. A. Manhart, gave a report on the financial condition of the Society and the membership. (See attached Exhibit C.) The report was accepted.

President Cecil Green read a letter from Mr. G. M. Kintz, Supervising Engineer of the United States Bureau of Mines, concerning a safety program which might be desirable for the Society to consider. President Green pointed out the desirability of establishing good safety programs but deferred any action on this matter until a joint council meeting to be held later in the week. Copy of Mr. Kintz' letter is attached to the report and shown as Exhibit D.

The chairman of the Constitution and By-Laws Committee, Dr. Wm. Rust, Jr., gave the report from this committee. It incorporated a complete analysis of the existing constitution passed during the year 1947 with recommended amendments. (Copy of this report is attached and shown as Exhibit E.)

The chairman of the Editorial Committee of the Geophysical Case Histories, Mr. Henry Cortes, presented this committee's report. He advised that Volume No. 1 would be published by approximately September 1948. At present, there are fifty-five papers which will make a total of six hundred pages in this volume. (A copy of this report is attached and shown as Exhibit F.)

The report of the Public Relations Committee was given by Business Manager Colin C. Campbell. The activities of this committee in bringing the Society to the attention of the public was reviewed by Mr. Campbell. Specific accomplishments were reviewed. (Copy of this report is attached and shown as Exhibit G.)

A report of the F.C.C. Allocations Committee was given by Chairman R. D. Wyckoff. He reported on the importance of keeping frequency allocation requirements of the industry before the F.C.C. and announced the meeting of his committee for interested parties which would take place Monday evening, April 26, in the Cosmopolitan Hotel.

The report of the Special Reviews Committee was passed. However, this report is attached and shown as Exhibit H.

A report of the Committee on Student Membership was passed. A copy of this report is attached and shown as Exhibit I.

The presentation of the Society Award for the Best Paper was made by President Cecil Green. Editor King Hubbert made a brief announcement of the objectives of the Society and the basis on which such a paper was chosen. The award was received by Mr. E. G. Leonarden for the recipient of the award, M. Raymond Maillet. Mr. Maillet's paper appeared in GEOPHYSICS under the title, "Fundamental Equations of Electrical Prospecting."

The results of the ballotting for new officers for the Society were announced by the chairman of the Nominating Committee, Mr. Cecil Green, as follows:

Number of ballots cast by the active members	824
Number of ballots disqualified for non-payment of dues	31
Number of ballots disqualified for other reasons	0

Results

For President:	
L. L. Nettleton	588
John H. Wilson	205
For Vice-President:	
R. L. Gilmour	407
W. J. Osterhoudt	370
For Secretary-Treasurer:	
E. V. McCollum	370
A. E. McKay	312
Total	793

Messrs. Nettleton, Gilmour and McCollum were therefore formally declared elected.

As there was no further business, the meeting was adjourned.

T. A. MANHART, *Secretary*

EXHIBIT A. VICE-PRESIDENT'S REPORT

According to the By-laws, the principal assigned task of the Vice-President of the S.E.G. is to "be responsible for all National Meetings of the Society." The first item in this responsibility is the selection of local committee chairmen to help in finding technical material for the annual meeting. This committee was duly organized last summer by finding men in the various centers of geophysical interest who would consent to serve as local chairmen and asking each of them to select his own local members. The names of this committee have been published in full in GEOPHYSICS (Vol. XII, No. 4 (Oct. 1947) p. 692). To them is due in large part whatever success the technical phases of the present meeting may have. Our thanks are due to them for the fact that we have over fifty papers and a very full session at this meeting.

A word about the symposium on geophysics in mining may be in order. The germ from which this symposium grew was planted at the local meeting last May in Tulsa at which Dr. Arthur A. Brant of Toronto gave a most interesting and stimulating talk. This was followed by a session in a hotel room which lasted far into the night, at which Dr. Brant, several officers of the Society and Tulsa members were present. It was then decided to hold the mining symposium at the Denver meeting. This has resulted in contacts with a number of geophysicists, geologists and executives in the mining industry which were completely unknown to many of us before and it is hoped that this will develop into a useful association.

The last item in which your Vice-President has been actively interested is the Cumulative Index of the publications of the Society. This was inherited from his previous job as editor of GEOPHYSICS. It is now completed and copies are available. Thanks are due to several of the staff of G.S.I., particularly Mr. Burg and his associates there, to O. F. Ritzmann of the Gulf Patent Department in Washington, and to R. M. Geyer of the Humble office in Houston, all of whom contributed substantially in assembling and classifying the material and in proofreading the results. Undoubtedly you will find many mistakes which have slipped through and some of you may not agree with the classification and arrangement which we have used. We only ask your indulgence in us as amateurs who have tried to produce an item which we feel will be a distinct aid in making geophysical literature generally much more useful and available.

EXHIBIT B. EDITOR'S REPORT

April 1947 to April 1948

During the period April 1947 to April 1948, four issues of GEOPHYSICS have been edited and have gone to press. These have included a total of thirty-nine (39) technical papers, and the total technical material including the Patents Section and Reviews of these four issues has amounted to about 514 pages.

Early in the present Editor's term of office, a need was felt for working out the details of the division of labor between the Editor and the Business Manager. On August 4, 1947, a conference was held between the past and present Editors and the Business Manager during which it was agreed that a logical division of labor between the Editor and the Business Manager would be for the Editor to be solely responsible for the technical articles, the Patents Section, Reviews Section, and the Contributors Section. In addition, the Editor would supervise the handing of abstracts of papers presented at annual and regional meetings, these being technical material. The Business Manager would in turn be responsible for departmental material including the Round Table, committee reports, accounts of meetings and similar material, as well as advertising. In addition, a schedule was worked out whereby a deadline for each issue was established at three months from the date of publication. Thus the press deadline for the January issue would be October 15; for the April issue, January 15, etc.

Beginning with the April 1948 issue, there has been a change of format of GEOPHYSICS. The page size remains the same but the printing covers a space $7\frac{1}{2} \times 4\frac{3}{4}$ inches instead of the $6\frac{3}{4} \times 4\frac{1}{8}$ inches formerly used. This brings the page format of GEOPHYSICS into conformity with that of the AAPG BULLETIN. This increases the number of words per page from approximately 430 to 500, and will result in a reduction of printing cost for the same material by $6\frac{1}{2}$ percent.

With the increase of the membership of the Society, it has been found necessary to increase the print order for GEOPHYSICS from 2,200 for 1947 to 2,500 for 1948.

During the past year a questionnaire has been circulated among members of the Society to determine the interest in republishing certain out-of-print back issues of GEOPHYSICS. It has been decided to reprint 200 copies each of the back issues in greatest demand.

In conclusion, the Editor wishes to express his appreciation of the excellent cooperation which he has received from the officers and members of the Society. He is especially indebted to the Business Manager, Colin Campbell, and Mrs. Campbell for their efficient handling of the business and non-technical aspects of GEOPHYSICS; to Mr. O. F. Ritzmann for his laborious compilation of the Patents Section, and to Mr. Richard A. Geyer and his colleagues on the Reviews Committee. In addition, he wishes to thank the contributors not only for their contributions but also for their courtesy and promptness in complying with editorial suggestions for revisions of their manuscripts. A final word of thanks is due to Miss Ava Eichenberg who as editorial assistant has handled most of the routine involved in getting out the Journal.

EXHIBIT C. TREASURER'S REPORT ON FINANCIAL CONDITION OF SOCIETY OF EXPLORATION GEOPHYSICISTS

A. Financial Position

1. *Assets*—Over-all increase of $2,638 for a total of $31,682 on December 31, 1947.
   a. Accounts receivable decreased by $62, reflecting the collection of several old accounts and the write-off of others. Balance of Accounts Receivable is $780.
   b. Inventory of *Early Geophysical Papers*—$1,142.
   c. Investments remain the same, at $18,880.
   d. Office equipment increased $201 for a total of $565.
2. *Liabilities*
   a. Current liabilities increased $378 for a total of $581.
   b. Deferred income—annual dues paid in advance—increased $1,549, for a total of $2,534.

B. Operations

1. *Net income decreased $2,881.*
2. *Reasons for the decrease:*
   a. Increased operating expenses brought about by:
      (1) Expansion of the business office.
      (2) Increased activity of the Society.
         (a) Expenses of regional meetings (three were held during 1947 while one was held during 1946)
         (b) Increased cost of stationery and office supplies which includes cost of printing and mailing ballots and surveys made by the Society.
   b. Increased cost of publishing GEOPHYSICS caused by:
      (1) Larger issues—Vol. 12, 1947, contained a total of 718 pages, an increase of 146 pages over Vol. 11, 1946.
      (2) Higher cost of printing per page—1947 GEOPHYSICS cost $1.02 per page more than the 1946 volume.
      (3) Total increase in the cost of printing GEOPHYSICS in 1947 over 1946 was $2,700, more than 95% of the decrease in net income of $2,881.
3. *Suggested remedies for the decreasing income:*
   a. Solicit additional advertisers for GEOPHYSICS.
   b. Raise advertising rates.
   c. Raise membership dues.

C. Report on Membership—December 31, 1947

Classification	*Number of Members*			
	1947	*1946*	*1945*	*1944*
Active Members	1,302	1,178	1,072	934
Associate Members	220	186	183	189
Student Members	68	12	5	7
Honorary Members (Living)	3	3	3	3
Totals	1,593	1,379	1,263	1,135
Increase over prior year	214	116	130	129

D. Report of Auditors

The report of the independent accountants for the year 1947 follows:

PRICE, WATERHOUSE, & CO.

1221 Locust Street
St. Louis 3
April 16, 1948

To the Executive Committee,
Society of Exploration Geophysicists,
Tulsa, Oklahoma.

We have examined the balance sheet of the Society of Exploration Geophysicists as at December 31, 1947 and the statement of net income for the year then ended. Our examination was made in accordance with generally accepted auditing standards and included such tests of the accounting records and other supporting evidence and such other procedures as we considered necessary in the circumstances, except that as instructed we did not apply the customary procedure of confirming receivables by direct communication with debtors.

The office staff is too small to permit the establishing of an effective system of internal accounting control, therefore we extended our tests of the transactions beyond those necessary where an adequate system is in force. While we did not make a detailed audit of all of the transactions, we compared the recorded cash receipts in totals with deposits shown on the bank statements for the year and examined paid checks, cash vouchers, and supporting data for all disbursements.

In our opinion, subject to the foregoing comments relating to the confirmation of receivables and to the system of internal accounting control, the accompanying balance sheet and statement of net income and the notes thereto present fairly the position of the society as at December 31, 1947 and the results of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

PRICE, WATERHOUSE & Co.

Society of Exploration Geophysicists

Balance Sheet—December 31, 1947

ASSETS

Cash		$10,314.48
Accounts receivable:		
Membership dues	$ 358.50	
Advertising	291.40	
Back numbers, reprints, and special publications	441.52	
Subscriptions	39.00	
	$ 1,130.42	
Less—Reserve for bad debts	350.00	
		780.42
Inventory of Early Geophysical Papers, at cost (Note A)		1,141.92
Investments, at cost:		
Farm and Home Savings and Loan Association of Missouri—fully paid investment certificate	$ 5,000.00	
United States Savings bonds	13,880.00	
		18,880.00
Office equipment	$ 693.76	
Less—Reserve for depreciation	128.43	
		565.33
		$31,682.15

LIABILITIES

Accounts payable		$ 561.52
Federal insurance contributions tax (Note B)		19.68
Deferred income:		
Membership dues	$ 1,417.08	
Advertising	203.50	
Subscriptions	913.17	
		2,533.75
Surplus:		
Balance, December 31, 1946	$27,856.02	
Net income for the year	711.18	
		28,567.20
		$31,682.15

SOCIETY OF EXPLORATION GEOPHYSICISTS

STATEMENT OF NET INCOME FOR THE YEAR ENDED DECEMBER 31, 1947

INCOME:			
Membership dues		$ 7,630.25	
Publications—			
Advertising	$5,174.70		
Subscriptions	2,535.14		
Back numbers	1,989.00		
Reprints	308.39		
Early Geophysical Papers	2,755.00		
Discounts allowed	(290.65)	12,471.58	
Interest received		260.00	$20,361.83
EXPENSES AND PUBLICATION COSTS:			
Salaries—			
Business manager and assistant		$ 2,400.00	
Office assistant		200.00	
Special stenographic work		179.70	
Commissions—			
Advertising—business manager		703.57	
Advertising—agencies		640.43	
Subscriptions—agencies		212.88	
Office rent		575.00	
Stationery and office supplies		1,243.31	
Telephone and telegraph		322.81	
Postage		788.72	
Traveling		69.01	
Annual and regional meetings		678.97	
Auditing		225.00	
Depreciation of office equipment		102.56	
Loss on disposal of office equipment		56.60	
Provision for bad debts		351.86	
Federal insurance contributions tax		14.68	
Miscellaneous		232.56	
		$ 8,997.66	
Publication costs		10,652.99	19,650.65
Net income			$ 711.18

Notes—

(A) The attached balance sheet does not reflect the inventory of back numbers and reprints of GEOPHYSICS, the cost of which was charged off at time of publication.

(B) Similar taxes for the period from January 1, 1937 to September 30, 1947 have not been paid and the liability therefor and for interest and penalties is not reflected in the balance sheet.

EXHIBIT D

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

April 22, 1948

Mr. Cecil H. Green
Vice President
Geophysical Service, Inc.
6000 Lemmon Avenue
Dallas 9, Texas

DEAR MR. GREEN:

Since the first of the year this office has received reports of three accidents that occurred when the firing line was blown across high-voltage lines during geophysical exploration work. One accident resulted in the death of the party chief; another, in the death of one of the shooting crew; and the third, in a near fatality.

At the Annual Meeting of the Society of Exploration Geophysicists in Denver in April, would it be possible for you to request the men attending the convention to establish a procedure which will eliminate this type of accident? Perhaps these men will assume the responsibility of making it mandatory for every geophysical party under their supervision to follow this established procedure.

As all members of the geophysical industry know the conditions that exist and the hazards involved when shooting near a high-voltage line, it should not be difficult to establish a mandatory procedure. The responsibility for eliminating this type of accident should be placed not only on the party chief but also on those who locate the hole, drill it, and shoot it.

Because of the decrease in the supply of other sources of power and the increase in the use of electricity, more rural and cross-country lines are being constructed, and the possibility that a high-voltage line will cross the property being examined is increasing rapidly. We believe that if all persons concerned will take the necessary time and precautions, the hole can be so located that it will not be near a high-voltage line.

One company is planning to print safety rules in red ink at the top of its daily field report. The safety rules could be printed in red ink on stickers and pasted at the top of the daily field report and on field correspondence.

Very truly yours,
(Signed) G. M. KINTZ
Supervising Engineer
District G

EXHIBIT E

January 12. 1948

Mr. C. H. Green, President
Society of Exploration Geophysicists
6000 Lemmon Avenue
Dallas 9, Texas

DEAR MR. GREEN:

The Constitution and Bylaws Committee of the Society of Exploration Geophysicists held a meeting in my office January 9, 1948, to consider the various objections raised to various provisions in the revised Constitution. While all revisions were approved by a large majority, the objections raised by a small minority appeared to the Committee to be so carefully considered that the Committee is of the opinion that amendments meeting these objections should be submitted to the membership of the Society.

The Committee respectfully submits the following list of amendments for consideration by the Council of the Society of Exploration Geophysicists at the annual meeting in Denver in April 1948. This list of proposed amendments will be published in the April issue of GEOPHYSICS prior to the annual meeting, and copies of these proposals will be submitted by private mailing to all active members of the Society in the immediate future, in order that they may be prepared to discuss them at the annual meeting of the Society in Denver.

Amendments

Amendment A. The membership class of Fellow is to be abolished and all references in the Constitution and Bylaws to Fellows shall be deleted. Any renumbering of sections necessitated by such deletion will be made.

Amendment B. Article III, Section 9, for the words "may not publish his affiliation with the Society," substitute the words "in publishing his affiliation with the Society shall clearly indicate his grade of membership."

Amendment C. Article IV, Section 1, delete Sections 1 and 2 and substitute therefore "Membership of any class shall be contingent upon conformance with the established principles of professional ethics." In Bylaws Article III, Section 3, delete second sentence and in Bylaws Article VI, Section 4, delete "shall be found guilty of a violation of the Code of Ethics of this Society, or."

Amendment D. Article VIII, Section1, before the words "District Representatives" delete the word "The" and add "and all elected." Cancel "and the chairmen of all standing committees." Article VIII, Section 3, at the end add "All committee chairmen shall attend this meeting, but, as chairmen, shall have no vote."

Amendment E. Article XII, Section 1, at end add "Council may designate Districts outside the area of the continental United States."

Amendment F. Cancel Article XII, Section 2.

Amendment G. Renumber Article XII, Section 3 as Section 2 and before the words "one District Representative," insert the words "for each seventy-five Active Members of the Society, who are not members of a Local Section,".

Amendment H. Amend Bylaws Article III, Section 5 by adding at the end "in the case of applicants for Student Membership, publication is not required. The Student Member shall be pronounced elected when approved by the Secretary-Treasurer."

Amendment I. Article IV, Section 3, delete the entire section. Renumber Sections 4 and 5, and in Section 2, after the word "Active" add the words "or Associate."

Very truly yours,
Constitution and Bylaws Committee
(Signed) W. M. RUST, JR., *Chairman*

WMR:ltj

EXHIBIT F. REPORT OF EDITORIAL COMMITTEE OF GEOPHYSICAL CASE HISTORIES VOLUME

April 26, 1948

Your Editorial Committee for the Geophysical Case Histories Volume is pleased to report that the Society has accumulated sufficient papers to publish a very creditable volume.

Thanks are due to the Committee members for soliciting and obtaining papers from a number of oil companies and others who have not previously published. Those companies and individuals are to be commended. Our appreciation is also due to A.A.P.G. and A.I.M.E. for allowing republication in whole or in part of some of the early papers. We are very fortunate in having Dr. L. L. Nettleton as editor.

In one volume we shall, therefore, have for ready reference a substantial number of new case histories, along with those previously published.

Our printer has now definitely advised we may expect publication in September 1948.

At present we have around 55 papers which will make a total of over 600 pages in the volume.

As soon as can conveniently be done, a price will be established and subscription cards will be circulated so that ample copies may be printed.

It should be noted that we lack papers from a very few companies who pleaded they were too busy, or who promised and have not delivered. For those, the Committee not only invites but strongly urges completion of one or more papers before June first. We feel that every company should be represented by at least one paper.

The volume will be designated No. 1, with the hope that in another two or three years we shall accumulate sufficient new papers for Volume 2.

Respectfully submitted,
(Signed) HENRY C. CORTES, *Chairman*

EXHIBIT G. REPORT OF THE PUBLIC RELATIONS COMMITTEE

At the annual business committee meeting held in Los Angeles, in 1947, the president of the Society of Exploration Geophysicists was authorized to appoint a new standing committee, namely the Public Relations Committee, to assist the Society in obtaining its rightful recognition and its separate identity mainly by means of guided publicity.

The following committee was appointed:

Geo. E. Wagoner—Chairman
M. R. Budd
Colin C. Campbell

During the year press releases were prepared on the following events:

1. Tulsa Regional Meeting, Tulsa, Oklahoma
2. Presentation of Exchange, Library to Tulsa University
3. Eastern Regional Meeting, Pittsburgh, Pennslyvania
4. Organization of Ark-La-Tex Geophysical Society, Shreveport, La.
5. Publication of the Volume of Early Geophysical Papers
6. Pacific Coast Regional Meeting
7. Organization of Pacific Coast Section of Society of Exploration Geophysicists
8. Houston Regional Meeting
9. Organization of the Houston Geophysical Society
10. Organization of the Dallas Geophysical Society
11. Local meetings of the various sections
12. Annual Meeting of Society of Exploration Geophysicists, Denver, Colorado, April 26–29

Favorable publicity was received in articles by Charles J. Deegen, published in the Oil and Gas Journal, May 31, 1947, and March 18, 1948, entitled "Geophysicists Entering a New Era" and "Trends in Geophysics," also an article written by Paul L. Lyons, "S.E.G. Marks 17 years of Growth."

In line with the Society's public relations policy, the executive committee set up and approved a Policy Regarding the Release of Technical Papers to trade journals. The public relations committee made available an experienced man to handle press releases at this annual meeting in Denver.

Other approaches made by the Society for increased recognition are as follows:

1. Proposed affiliation with the American Geological Institute, an instrument of the National Research Council which is an agency of the National Academy of Sciences.
2. Appointment of a committee to represent the Society at the International Geological Congress in London, August 25–September 1, 1948.
3. Encouragement of members of Society of Exploration Geophysicists to present papers before other interested groups.

4. Consideration of the proposed A.I.E.E.-R.I.E.-S.E.G. liaison committee to function between the A.I.E.E.-R.I.E.-S.E.G. in the field of electronic application.
5. Increase in the personnel of the Business Manager's office and the increase in office space so that the business of the Society can be properly handled.
6. The organizing of local and student chapters of S.E.G. in various parts of the country. The organization of local and student chapters has probably presented to the public and the petroleum industry, the importance of the Society more than any other one thing.
7. Representation on F.C.C. Committee.
8. Publication by the Society of the Vol. 1 Case Histories.
9. Plans for having a display booth at the 1948 Oil Exposition in Tulsa, Oklahoma.

Respectfully submitted,
Public Relations Committee
GEO. E. WAGONER, *Chairman*

EXHIBIT H. REPORT OF SPECIAL REVIEWS COMMITTEE

March 30, 1948

Mr. T. A. Manhart
Seismograph Service Corporation
P. O. Box 1590
Tulsa 1, Oklahoma

DEAR SIR:

In accordance with your letter of October 8, 1947, I am presenting a summary of the activities of the Special Reviews Section of GEOPHYSICS for the issues July 1947 through April 1948. The titles of the reviews and their abstractors for this period are enclosed. During this time 22 articles and books were reviewed by six different reviewers. The majority of the material reviewed included relatively inaccessible foreign references published in Denmark, Italy, England, Russia, Canada, France and Switzerland.

It is hoped that both the scope and quantity of future material to be analyzed by the Reviews Committee will be broadened during the coming year. It should be stressed that one of the functions of the members of the Committee is to request reviews on occasion from others who may have wider experience in the fields of potential review material. This policy should add greatly to the usefulness of the Reviews Section of GEOPHYSICS for the membership at large in providing reviews or better quality over a much wider range of subjects than could otherwise be accomplished.

Very truly yours,
(Signed) R. A. GEYER

July 1947

Geological Factors and Gravity Interpretation Illustrated by Evidence from India and Burma, by P. Evans, and W. Crompton, "Quarterly Journal of the Geological Society of London," Vol. CII, pp 211–249, December 30, 1946.—(L. L. Nettleton)

Geophysical Work of the National Geological Survey of China and of the Institute of Physics of the National Academy of Peiping of China, by Wen Hao Wong, "Terrestrial Magnetism and Atmospheric Electricity," Vol. 52, No. 1, pp. 77–79, March 1947.—(R. A. Geyer)

The Vehicular Odograph, by A. G. McNish and Bryant Tuckerman, "Terrestrial Magnetism and Atmospheric Electricity," Vol. 52, No. 1, pp. 39–66, March 1947.—(R. A. Geyer)

October 1947

Geophysical Work in South Africa, By B. D. Mares, "Geological Survey" Pretoria, Union of South Africa.

Gravity Measurements in Sjaelland, Men, Falster, and Lolland by Means of the Askania-Gravimeter, by Einar Anderson, Geodaetisk Instituts Skrifter. 3. Raekke Bind X. København—1947, 69 pages, 17 figures.

La Rete Geofisica e Geodetica in Italia nel Suo Stato Attuale e Nei Suoi Rapporti con la Struttura Geologica Superficiale e Pronfonda, by Carlo Morelli, Institute Geofisico—Trieste. Publ. n. 222. Trieste—1946, 77 pages, 3 plates, 11 figures.—(R. A. Geyer)

Photoelectric Cells, A. Sommer, Ph.D. Formerly, Cinema Television Co., Ltd. Chemical Publishing Co., Inc. New York (102 pages, $2.75). 1947—(A. J. Herzenberg)

January 1948

Report on Activities of the Associate Committee on Geodesy and Geophysics of the National Research Council of Canada for April 1 Through June 30, 1947. (30 pages)—(R. A. Geyer)

Seismic Measurements on the Ross Shelf Ice by Thomas C. Poulter, Transactions American Geophysical Union, Part I. Vol. 28, No. 2, pp. 162–170, April 1947. Part II, Vol. 28, No. 3, pp. 367–384, June 1947.—(Milton B. Dobrin)

Pulse of the Earth, by J. H. F. Umbgrove. The Hague—Martinus Nijhoff—1947.—(R. A. Geyer)

April 1948

Theory of Electrical Well Logging by L. M. Alpin, Moscow, 1938, 88 pages.—(Hubert Guyod)

Electrical Well Logging. Interpretation of Electric Logs by V. N. Dakhnov, Moscow, 1941, 496 pages.—(Hubert Guyod)

An Investigation into the Value of the Seismic Methods in Delineating Structure in Southwestern Ontario by John H. Hodgson, 56th Annual Report of the Ontario Department of Mines, Vol. 56, Part 4 (1947).—(Milton B. Dobrin)

Oil Fields of Greater Oficiana Area Central Anzoategui, Venezuela by H. D. Hedberg, L. C. Sass, and H. J. Funkhouser, Bull. A.A.P.G., Vol. 31, pages 2089–2169 (1947).—(Milton B. Dobrin)

Biochemical Prospecting for Copper and Zinc By H. V. Warren and C. H. Howatson, Bulletin Geological Society of America, Vol. VIII, pages 803–820 (September 1947).—(L. L. Nettelton)

The Zinc Content of Plants of the Friedensville Zinc Slime Ponds in Relation to Biogeochemical Prospecting by W. O. Robinson, H. W. Lakin, and Laura E. Reichen, Economic Geology, Vol. XIII, pages 572–582 (1947).—(Milton B. Dobrin)

La Prospection Electrique du Sous-Sol (*Electrical Prospecting*) by E. Poldini, Lausanne, 1947, pages 120.—(R. A. Geyer)

Anwendung der Fourier-Saetze in der Theorie der Seismographen und Schwingungsmesser (*Application of Fourier Analysis in the Theory of Seismography and Oscillatory Measurements*) by F. Gassman. Elemente der Mathematik Mitteilungen aus dem Institut fuer Geophysik, Bd. 11/3, 1947, Pages 58–63.—(M. M. Slotnick)

Mesures de Pesanteur Executees Dan le Sud-est de la France en 1941. Description Gravimetrique de La Region Nord des Alpes Francaises (*Gravity Observations Made in the South-East of France in 1941. Gravimetric Description of the Region North of the French Alps*) by Pierre Lejay. Comite national francaise de geodesie et geophysique, Paris, 1942, pp. 89–95 and 97–102 and map facing 102.—(R. A. Geyer)

Mesures de Pesanteur Executees Dans le Sud de la France en 1940. Etude Theorie de L'Attraction des Couches Minces. Application A L'interpretation des Anomalies Regionales (*Gravity Observations made in the South of France in 1940. Theoretical Studies of the Attraction of Thin Beds. Application to the Interpretation of Regional Anomalies*) by Pierre Lejay, Comite nationale francaise de geodesie et geophysique, Paris, 1942, pp. 52–98.—(R. A. Geyer)

Research, A Journal of Science and its Applications. Butterworths Scientific Publications Ltd. London, October 1947.—(R. A. Geyer)

Nucleonics, The McGraw-Hill Magazine of Nuclear Technology, October 1947.—(R. A. Geyer)

EXHIBIT I. REPORT OF THE COMMITTEE ON STUDENT MEMBERSHIP

The Committee on Student Membership was first appointed in June 1946, and its objective was to inform under-graduate and graduate students of the nature of Applied Geophysics as a positive means of enrollment of student members. The committee is composed of the following members:

James C. Menefee, Chairman
Professor John H. Hodgson
R. S. Jackson
Dr. C. H. Dix
Professor Ralph C. Holmer
Professor Darrell S. Hughes
Professor V. L. Jones
Professor S. A. Lynch

During 1947 local chapters were organized at the University of Tulsa, and the Colorado School of Mines and petitioned the Society of Exploration Geophysicists for affiliation. These petitions were approved unanimously by the Executive Committee in March 1948.

The University of Tulsa Student Geophysical Society has an enrollment of 33 members, of which 26 are student members of the Society of Exploration Geophysicists. Under the able sponsorship of Professor V. L. Jones, the chapter is now well organized. Mr. Chet H. Jameson, Jr., was elected President. One guest speaker has already appeared before this group, and arrangements have been made for another in the near future.

The Colorado School of Mines Society of Student Geophysicists has an enrollment of 31, and 22 have already applied for membership in the Society of Exploration Geophysicists. This chapter was very ably sponsored by Professor R. C. Holmer, and elected Mr. H. G. McCleary its first President. One guest speaker has visited this chapter.

Professor John H. Hodgson, of the University of Toronto, has started a series of Seminars at which subjects related to geophysics are discussed, and several new student members have been enrolled in the Society due primarily to these meetings.

The possibility of organizing a chapter at the California Institute of Technology was looked into but dropped when it was found that the administration objected to it, since a very active geological club included a large proportion of students interested in geophysics.

The Executive Committee acted favorably on the following recommendations made to it by this committee:

1. That a method be worked out whereby quicker action could be taken on applications for student membership.
2. That a model constitution be submitted to students to aid in organization of new chapters.
3. That the Society of Exploration Geophysicists look favorably on the policy of allowing student membership to students in good standing, regardless of class, i.e. freshmen, seniors, etc., as long as they are recommended by a faculty member.
4. That a short application form for students be issued.
5. That complimentary subscriptions to GEOPHYSICS be donated to each student chapter.

We are pleased to report that during 1947–1948 a total of 92 applications for student membership were approved.

We recommend that the new committee of student membership consider the following:

1. Encourage and assist in the formation of new chapters at colleges and universities.
2. Arrange to have guest speakers visit the student chapters.
3. Encourage students to write articles for publication in GEOPHYSICS.
4. Publish reports in GEOPHYSICS on activities of student chapters.

Respectfully submitted,
Committee on Student Membership
(Signed) J. C. MENEFEE, *Chairman*

April 22, 1948

RAYMOND MAILLET

The Annual Best Paper Award for the year 1947 was presented to M. Raymond Maillet, Technical counsel for Compagnie Generale de Geophysique, Paris, France, for his paper entitled "The Fundamental Equations of Electrical Prospecting" (GEOPHYSICS, Vol. XII, No. 4, October 1947, page 520). E. G. Leonardon, who translated the paper from the French, received the Certificate and Medallion for M. Maillet (Below, left to right, Cecil H. Green, President, E. G. Leonardon and M. King Hubbert, Editor of GEOPHYSICS).

PAPERS PRESENTED AT MEETINGS OF THE LOCAL SECTIONS

FORT WORTH

May 10, 1948:

Seismic Operations in Venezuela. J. R. Maxey, Chief Geophysicist, Pan-American Geophysical Company.

TULSA

May 13, 1948:

Ocean Basins. Maurice Ewing, Associate Professor of Geology, Columbia University

ANNOUNCEMENTS

JOINT ANNUAL MEETING
JEFFERSON HOTEL, ST. LOUIS, MARCH 14–17, 1949
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
SOCIETY OF EXPLORATION GEOPHYSICISTS

The joint annual meeting of the three petroleum exploratory societies will be held at the Jefferson Hotel, St. Louis, Missouri, on March 14, 15, 16, and 17, 1949.

The official from of "Application for Accommodations" is being mailed to each member this month (July). The following copy is published here for information, not for return.

All requests for hotel rooms should be made by returning the attached form to the American Association of Petroleum Geologists, Hotels Reservation Bureau, 1420 Syndicate Trust Building, St. Louis 1, Missouri. Requests for reservations should be made as far in advance of February 14, 1949, as possible, and should contain all information requested on the attached form. Receipt of requests will be acknowledged and filed in order of receipt at the Housing Bureau. Actual assignments will be made in the various hotels and confirmations will be mailed about 60 or 90 days prior to the convention. Members who request reservations, but later find they can not attend should notify the Hotels Reservation Bureau without delay. Blocks of rooms will not be reserved. All rooms must be reserved in the names of individuals.

This notice is being mailed simultaneously to the members of the three societies. Officers, representatives, and committee members, particularly, are requested to reply promptly.

The executive committees of the societies constitute the committee for arrangements and program. Certain convention chairmen will be named and necessary details will be announced later. As no local group is sponsoring this meeting, special features of recent annual meetings will be omitted. Entertainment is to be on a pay-as-go basis. A reasonable registration fee will be charged.

THE EXECUTIVE COMMITTEES

Tulsa, Oklahoma
July 15, 1948

APPLICATION FOR HOUSING ACCOMMODATIONS, ST. LOUIS, MO.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, MARCH 14–17, 1949

For your convenience in making hotel reservations for the coming joint meeting of the American Association of Petroleum Geologists, The Society of Exploration Geophysicists and the Society of Economic Paleontologists and Mineralogists, March 14–18, 1949 in St. Louis, hotels and their rates are listed below. Use the form at the bottom of this page, indicating your first, second and third choice. Because of the limited number of single rooms available, you will stand a much better chance of securing accommodations if your request calls for rooms to be occupied by two or more persons. All reservations must be cleared through the housing bureau. ALL REQUESTS FOR RESERVATIONS MUST

GIVE DEFINITE DATE AND HOUR OF ARRIVAL AS WELL AS DEFINITE DATE AND APPROXIMATE HOUR OF DEPARTURE, ALSO NAMES AND ADDRESSES OF ALL PERSONS WHO WILL OCCUPY RESERVATIONS REQUESTED *must* BE INCLUDED.

Hotel	*For One Person*	*For Two Persons*		*2-Room Suites*
		Double Bed	*Twin Beds*	*Parlor and Bedroom*
Baltimore	2.75–3.50	3.75– 4.50	4.00– 5.00	
*Claridge	3.00–4.00	4.00– 6.50	5.00– 6.50	10.00 & Up
*DeSoto	2.75–7.00	4.00– 7.00	6.00–12.00	10.50–12.00
*Jefferson	3.50–6.00	5.00– 7.00	7.00– 8.00	14.00–22.00
*Lennox	3.25–6.00	5.00– 6.50	6.00– 8.00	11.00
*Majestic	2.25–3.50	3.00– 4.00	5.00	
*Mark Twain	3.00–3.50	4.50– 5.00	5.00– 5.50	
*Mayfair	3.25–7.00	5.00– 8.00	6.00– 8.00	11.00 & Up
Melbourne	3.50–6.00	5.50– 6.50	6.00– 8.50	12.00–15.50
Sheraton	3.50–6.00	5.25–10.00	5.50–11.00	8.50–15.00
*Statler	3.50–6.00	5.25– 8.00	7.27–10.00	16.00–19.00

*Downtown
In the event that the hotel room rate structure is changed prior to the above convention, the rates will be changed accordingly.

ALL RESERVATIONS MUST BE RECEIVED PRIOR TO: February 14, 1949
American Association of Petroleum Geologists
Hotels Reservation Bureau,
1420 Syndicate Trust Building,
St. Louis 1, Mo.

Please reserve the following accommodations for the Joint convention of the A.A.P.G., S.E.G., S.E.P.M., in St. Louis, Missouri, on March 14–17, 1949
Single Room.....Double Bedded Room.....Twin Bedded Room.....
2 Room Suite.....Other Type of Room.....
Rate: From $.....to $.....
First Choice Hotel.....
Second Choice Hotel.....
Third Choice Hotel.....
Arriving at Hotel (date).....hour.....A.M.....P.M. Leaving (date).....
hour.....A.M.....P.M.

THE NAME OF EACH HOTEL GUEST MUST BE LISTED. Therefore, please include the names of *both* persons for *each* double room or twin bedded room requested. Names and addresses of all persons for whom you are requesting reservations and who will occupy the rooms asked for:

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.....
.....
.....

(Individual Requesting Reservations)

Name.....
Address.....
City and State.....

If the hotels of your choice are unable to accept your reservation the Housing Bureau will make as good a reservation as possible elsewhere providing that all hotel rooms available have not already been taken.

THE NATIONAL RESEARCH COUNCIL
COMMITTEE ON GEOPHYSICS,
ADVISORY TO THE OFFICE OF NAVAL RESEARCH

Acting upon a request from Admiral Paul F. Lee, Chief of Naval Research, the National Research Council has appointed a Committee of active scientific investigators to advise the Geophysics Branch of the Office of Naval Research regarding scientific and related aspects of their research programs. The Committee is as follows:

Walter H. Newhouse (Chairman), Harry H. Hess (Vice Chairman),
Roland F. Beers, Maurice Ewing, Ellis A. Johnson, Lester E. Klimm,
William C. Krumbein, William W. Rubey, and J. Frank Schairer.

Dr. R. C. Gibbs, Chairman of the Division of Mathematical and Physical Sciences of the NRC, acts as Administrative Adviser to the Committee, in collaboration with Dr. Arthur Bevan, Chairman of the Division of Geology and Geography.

The Committee held its first meeting on January 7 and 8, 1948, in Washington, D. C. As stated by Dr. Roger Revelle, Head of the Geophysics Branch of the Office of Naval Research, that Branch is charged with the responsibility within the Navy Department of sponsoring basic research in appropriate fields of earth sciences through financial and other support of worthy projects. Functioning within this general framework of responsibility the Committee will, for the present, restrict its consideration to research problems dealing with the crust of the earth and the properties of the earth as a whole.

Since it is part of the policy of ONR to sponsor research in fields not adequately covered by other agencies, the Geophysics Branch, with the Committee's concurrence, has established the following objectives for Research within the fields covered by the Committee:

1. To foster, in cooperation with other agencies, geological, geographical, and geophysical explorations of little known areas of the earth such as the islands of the Western Pacific and the Arctic and Antarctic. Such explorations may include all aspects of the natural environment and problems of human and economic geography and ethnography as well as the more limited objectives implied in the terms geology and geophysics.
2. To conduct laboratory and field studies leading to a greater understanding of the properties and processes existing in the outer hundred kilometers of the earth's crust.
3. To develop instruments and techniques for determination of the earth's properties; for example universal airborne magnetometer equipment.

The Office of Naval Research has adopted the policy of avoiding formulation, detailed direction, and "farming out" of projects for basic research in the belief that maximum progress and results will be realized if projects for investigation grow out of the ideas and interests of the investigators themselves. The Committee warmly endorses this policy and will seek at all times, through advice and recommendations, to further its operation to the maximum degree possible. The submission of significant and well-organized research proposals will be helpful in this connection.

The Geophysics Branch of ONR has asked the Committee

1. To advise it on the over-all objectives of the ONR basic research program in this field.
2. To encourage the submission of worthwhile research proposals.
3. To evaluate the scientific merits of proposals received and recommend appropriate action thereon.

The Advisory Committee on Geophysics has formulated, chiefly for its own guidance, certain bases for evaluating research proposals, as follows: (These are subject to change as further experience may indicate. The order of listing at any point is not to be regarded necessarily as the order of importance.)

1. General
   a. Preference should be given to specific individual proposals in contrast to multiple proposals, the several parts of which are not closely related.
   b. It is desirable that proposals be submitted in the name of the individual or individuals who will be actively engaged in the proposed investigations.
2. Scientific Merits
   a. Would the solution of the problem be important to the progress of the science of Geophysics; that is, would the solution lead to new problems rather than to a cul de sac?
   b. Does the problem appear capable of solution by the techniques proposed?
   c. Will the conduct of the research lead to valuable training of younger scientists?
   d. Does the problem to be investigated lie within the Research objectives of the Geophysics Branch of ONR?
   e. Are important unforeseen results likely to come out of the research?
   f. Is the investigation timely in relation to other contributary operations?
3. Qualifications of the investigator and adequacy of proposed project
   a. Are the training, experience, and demonstrated ability of the principal investigator suitable for the project?
   b. Are the assisting personnel and the equipment available for the project adequate?
   c. Is the budget submitted commensurate with the requirements of the project?
4. Possibilities of undesirable duplication.

For further details consult the Office of Naval Research, Navy Department, Washington 25, D. C., or the National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

ORGANIZATION OF THE PACIFIC COAST SECTION OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS

At 6:30 P.M. on March 11, 1948 about ninety persons assembled in the Palm Room of the Bakersfield Inn, at Bakersfield, California. Mr. M. C. Born was chairman of the meeting. Notices previously

Standing, JOHN SLOAT. *Seated, left to right,* O. F. VAN BEVEREN, C. H. JOHNSON, M. C. BORN, E. H. VALLAT, T. P. ELLSWORTH, L. B. SNEDDEN *and* R. A. PETERSON.

had been circulated announcing this dinner meeting was called for two chief purposes. The first purpose was officially to organize the Pacific Coast Section of the Society of Exploration Geophysicists.

The second purpose was to enjoy the good fellowship that always exists when geophysicists assemble. At the conclusion of the meeting it generally was agreed that both aims had been achieved.

During dinner and at intervals during the business meeting various persons related experiences, stories, and "doodle-bug" testimonials.

Messrs E. H. Vallat and T. P. Ellsworth presented reviews of the activities of the unofficial Pacific Coast group that has been active for some years. A Constitution and By-Laws drafted by a committee composed of Messrs C. H. Johnson, Chairman, L. B. Snedden, and O. F. Van Beveren were accepted by the persons present. The Nominating Committee composed of Messrs E. H. Vallat, chairman, M. C. Born, C. H. Dix, T. P. Ellsworth, and J. J. Jakosky presented a list of candidates. The following officers were elected:

President:

Curtis H. Johnson, General Petroleum Corporation

Vice President, Northern District:

Loring B. Snedden, The Texas Company

Vice President, Southern District:

M. W. Harding, United Geophysical Company

Secretary-Treasurer:

R. C. Dunlap, Jr., Geophysical Service Incorporated

Executive Committee (Past Presidents):

O. C. Lester, Jr. (2 year term), Amerada Petroleum Corporation (retired)
Henry Salvatori (1 year term), Western Geophysical Company

District Representatives:

John Sloat (2 year term), Union Oil Company of California
Dean Walling (1 year term), Western Geophysical Company

Near the conclusion of the meeting a petition was circulated for signature. The petition requests the Council of the Society of Exploration Geophysicists officially to recognize this group as the Pacific Coast Section of the Society of Exploration Geophysicists.

Plans of the new organization include two technical meetings each year, the next one being scheduled for late May in Bakersfield and the following one for early November in Los Angeles. Regular informal luncheon groups will meet in Bakersfield and in Los Angeles, the former group having been functioning under the leadership of T. P. Ellsworth, Richfield Oil Corporation, for about eight months already.

Programs and activities will be planned to appeal to geologists and to well surveying and other service engineers, and, from time to time, aspects of mining geophysics will be considered. Participation by the younger geophysicists, by students, and by other interested persons not qualifying for active membership in the national organization of the Society of Exploration Geophysicists also will be encouraged, to the end that the new Section may exert the broadest possible stimulus to exploration on the Pacific Coast.

Persons attending the meeting are optimistic regarding the future success of the organization. Widespread interest is indicated by the number present, as well as by the long distances traveled by many individuals.

R. C. DUNLAP, JR.
Secretary-Treasurer
126 George Hay Building
Bakersfield, California

PERSONAL ITEMS

MEMORIAL

GRAHAM D. KENDALL
(1907–1948)

Graham Kendall, better known as "Dotty" to his family and friends, died of complications resulting from sarcoma in St. John's Hospital, Tulsa, on May 1, 1948. He had been aware of the malignant nature of the disease for more than a year, but cheerfully kept on with his work until two weeks before his death. Dotty was active in geophysical exploration for nearly twenty years. He was highly regarded for the excellence of his professional work, and he was widely known among a large circle of friends who shared his interest in a variety of hobbies.

Dotty was born in Dallas July 15, 1907. Two brothers and four sisters gave him his nickname, "Dotty", from the polka dot rompers he wore as a small boy. When he grew up he adopted "D" as his middle initial.

He and his brothers took up radio as a hobby in its early days, and in 1918, when he was eleven, Dotty held an amateur license. Stamp collecting was another school boy hobby. After attending high school in Dallas, Dotty entered Rice Institute in Houston. He left school in 1928 to spend a year on refraction seismograph parties operated by Geophysical Research Corporation for Louisiana Land and Exploration Company. Then he returned to Rice Institute and graduated with a B.A. degree in physics. While at Rice he became interested in astronomy and built the first of several telescopes which he constructed for his own pleasure. In 1930 Dotty was employed as observer on a seismograph party operating for Amerada Petroleum Corporation in Oklahoma. The wanderings of the party took him to Chickasha where he met and married Ocey Mae Jenkins in 1931. They became the parents of two children, Graham Logan who is now 15, and Judith Ann who is 10. Dotty was promoted to party chief in 1934 and he directed exploration work in Kansas, Mississippi, New Mexico, Oklahoma, and Texas. During his employment with Amerada Dotty continued his interest in radio and astronomy, and also took up oil painting, color photography, and piano playing. Fishing was always one of his favorite sports and led to tying flies. This hobby developed into a small business.

In 1945 Dotty became supervisor of geophysical operations for Deep Rock Oil Corporation. He was responsible for the detail shooting and interpretation of data which led to the discovery of the West Shawnee Lake field in 17-10 N-2 E, Pottawattamie County, Oklahoma. With his family located in Tulsa in a permanent home Dotty engaged in gardening in the same vigorous manner with which he had pursued his other hobbies.

Dotty was a member of the Society of Exploration Geophysicists, The Tulsa Geological Society, and the Geophysical Society of Tulsa. His associates in these societies and his friends everywhere regret his untimely death and extend their sympathy to his family.

FRANCIS F. CAMPBELL

Tulsa, Oklahoma
May 12, 1948

JAMES B. MCKEE resigned his position with the Shell Oil Company, Inc. on April 30, 1948 and is now employed as Jr. Seismologist for Magnolia Petroleum Company. His new address is 220 West Second Street, Odessa, Texas.

DALLAS R. DAVIS has been named Manager of the Tulsa Store of the Harrison Equipment Company. The new Tulsa branch of the company is located at 1134 E. 4th Street, Tulsa. Simultaneously Harrison opened another new branch store, managed by J. W. Stanfield, at 6234 Peeler Street, Dallas, Texas.

ALFRED J. HERMONT is the name legally adopted by Alfred J. Herzenberg, Research Geophysicist for Shell Oil Company, Inc. His home address is 2511½ Bellaire, Houston 5, Texas.

A. B. HAMIL, President, announces that the Marine Exploration Company has moved into a new exploration building at 3732 Westheimer Road, Houston, which will afford the firm much larger quarters and more extensive laboratory facilities. With this move into larger quarters, Marine Exploration will increase their personnel, both in the administrative and technical branches of their work. The company has offices in Houston and New Orleans with field crews working throughout the oil country.

EWIN D. GABY announces the organization of the Delta Exploration Company, Inc., 418½ East Pearl Street, Jackson, Mississippi. Mr. Gaby, President and Supervisor for the new company, was formerly Supervisor for Geophysical Service Inc. Other administrative personnel of the company are: John J. Babb, Secretary-Treasurer and Supervisor, formerly Party Chief with Geophysical Service Inc.; George Augustat, Vice President and Party Chief, formerly Party Chief with Geophysical Service Inc.; Audio G. Harvey, Vice President and Party Chief, formerly Party Chief with Geophysical Service Inc.; and Etoyle Conly, Vice President and Field Supervisor, former Supervisor for Geophysical Service Inc. Mr. Conly, the only non-member of S.E.G. among those named, has applied for membership.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it to the President within thirty days. (Names of references appear in parentheses after the name of each nominee.)

ACTIVE

James Thurman Capp (M. P. Jones, J. W. Horn, Cecil H. Green)
Edward Hermus Champ (H. Hallock Brown, W. W. Newton, J. E. Jett)
George Clifford Colley (Robert H. Ray, J. C. Pollard)
Chris Harold Elston (John M. Sturdevant, Virgil Teufel, Kenneth E. Burg)
Robert Dixon Everett (Cecil H. Green, H. B. Peacock, Fred J. Agnich)
Charles Gullette Faubion (Byron K. Johnson, A. E. McKay, C. H. Hightower)
Rowland Kenneth Gilbert (Maynard W. Hardy, Raymond A. Peterson, Lawrence K. Morris)
Ben Rollins Howard (M. P. Jones, J. W. Horn, Roe W. Carson)
Robert Combs Kendall (C. C. Ludwick, G. D. Lambert, R. F. Christy)
Charles Collett Smith (W. J. Osterhoudt, Malcolm S. Morrison, E. E. Unger)
Wentworth J. Tellington (W. H. Siefert, H. C. Cortes, E. J. Handley)
James Kemp Ziegler (A. W. Farmilo, C. M. Moore Jr., Cecil H. Green)

ASSOCIATE

Julius Emmett Arceneau (Ernest Kiesler, Robert Dunlap, Cecil H. Green)
Burl J. Boring (L. E. Whitehead, B. G. Swan, H. R. Prescott)
John Edwin Bramlette (H. B. Peacock, John M. Sturdevant, Kenneth E. Burg)
Walter Dudley Coursey (C. H. Green, K. E. Burg, E. J. Stulken)
Joe Harrell Deer (M. P. Jones, J. W. Horn, B. F. Owings, Jr.)
Richard Longley Fentem (Paul H. Jeffers, A. I. Innes, Junius O. Laws)
Roy Lee Fuller (R. C. Dunlap Jr., E. A. Kiesler, Cecil H. Green)
Franz M. Hawpe (R. H. Tucker, G. D. Gibson, Frank B. Smith)
Wallace F. Huey (T. R. Shugart, E. A. Fain, Bob Wallace)
Marshall Lee Mason Jr. (B. F. Owings Jr., J. W. Horn, M. P. Jones)
John Herbert McKeever Jr. (A. W. Farmilo, C. M. Moore Jr., Ralph C. Holmer)
Jack Maurice Proffitt (H. B. Peacock, John M. Sturdevant, Kenneth E. Burg)
Herbert G. Rim (Paul E. Swenson, Robert Dunlap, Francis A. Hale)
John Joseph Schneider Jr. (R. F. Bennett, A. E. McKay, L. F. Fischer)
George Oliver Shettle (G. W. Carr, M. H. McKinsey, L. F. Fischer)
Wilson C. Spicer (A. B. Bryan, R. W. Gemmer, Paul Lyons)
Paul Ladell Walton (Floyd J. Williams, C. H. Green, F. J. Agnich)

STUDENT

John Jay Jakosky Jr. (Cecil H. Green, L. L. Nettleton, Henry C. Cortes)

TRANSFER TO ACTIVE MEMBERSHIP

James G. Jackson Jr. Charles T. Rankin William B. Wiley Jr.

TRANSFER TO ASSOCIATE MEMBERSHIP

Albert W. Musgrave

REINSTATEMENT

R. Ellis Smith M. M. McCaleb

DECEASED

Graham D. Kendall Paul H. Boots